ARCAS

New assessment Methodology for social, sustainable and eco-friendly housing. Climate architecture for the Sudoe's area

USER'S GUIDEBOOK

-

DIAGNOSTICS AND EVALUATIONS – ARCAS TOOL

[ARCAS – Arquitectura para el Clima (arcassudoe.eu)](https://arcassudoe.eu)

CONSEJERÍA DE OBRAS PÚBLICAS, ORDENACIÓN DEL TERRITORIO Y URBANISMO

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ARCAS - New assessment Methodology for social, sustainable and eco-friendly housing. Climate architecture for the Sudoe's area,

User Guidebook: Diagnostics and evaluations – ARCAS tool (Publication version 0.1)

Abstract

ARCAS focuses on the 'SUDOE's climatology and offers an instrument, based on key indicators, to allow the design of buildings, which maximize the energy efficiency and the air quality and promote the social well-being thanks to the use of the best available techniques.

This project has received funding from the European Union's Interreg Sudoe Programme under grant agreement no SOE3/P3/E0922

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II – User's guidebook

II.1 - ARCAS tool overview

II.1.1 – Who can make use of this guidebook ?

The ARCAS tool is developed with the aim of providing:

- A common methodological framework
- A multi-criteria methodology thanks to the ARCAS tool
- A link between Certifier and User

It is intended for users who wish to obtain information about the ARCAS methodology when using it. The ARCAS project defines two profiles:

- User profile

The technician checks the initial situation of the building by estimating the indicators that define the 3 indicated axes.

Knowing the initial situation of the building, the tool allows to simulate possible changes by providing a comparison between the initial situation and the different simulations. These benchmarks help decision-making in the measures to be implemented.

- Certifier profile

For the certification of the building with the ARCAS method, the values that are measured or calculated are introduced in the tool, the estimation of these is not valid.

II.1.2 – How the ARCAS tool works ?

The ARCAS project aims to develop an evaluation and design methodology aimed at the rehabilitation of buildings and groups of collective buildings of social housing, with the aim of addressing energy poverty and promoting sustainable rehabilitation, energy efficiency and health in the Sudoe territory. The project is based on the integration of three research axes:

- Autonomy/energy efficiency
- Social quality/Energy poverty
- Indoor environment quality/health

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As a result of this integration, it is intended to determine the optimal relationship between the 3 axes mentioned and obtain the best energy efficiency while maintaining social quality and the well-being of citizens.

ARCAS is based on the use of similar climatology in the South Atlantic Arc for the development of a tool that allows, through key indicators, the design of building architecture based on maximizing energy efficiency, air quality and thus promoting social welfare, making use of the best available techniques, including renewable energy sources.

This project joins forces for the development of strategies and measures that facilitate national, regional and local governments to develop policies for the rehabilitation of collective buildings of housing of great autonomy and energy efficiency (axis 1), with a healthy air quality for the occupants of the buildings (axis 3) and reducing energy poverty so important in many European countries (axis 2).

To define the assessment of the building according to these three axes, indicators are considered within each axis, which, will be estimated, measured or calculated depending on the phase in which we are.

The result is a traffic light that indicate the evaluation of the building according to the ARCAS project.

Once known the initial state of the building with the measured values, the simulation is performed, with the calculated values, of the project to be developed defining the proposed measures according to the 3 axes that define ARCAS. This project proposal results in a Pre-certification in the ARCAS tool, which will allow access to possible grants, financing, etc.

Once the works are completed, the indicators that define the 3 axes are measured, thus obtaining the final situation of the building rehabilitated in ARCAS. The tool provides a comparison between the initial situation of the building before the works and the current situation completed the works.

After a period of time to define the useful life of the building, measuring again the indicators, the final certification is obtained in ARCAS.

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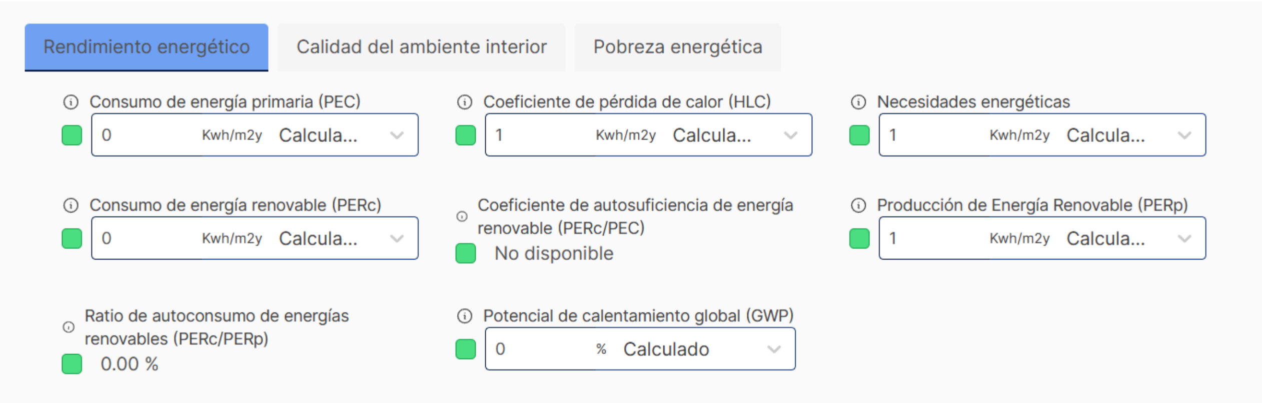
- AXIS 1: Energy efficency. -

To define the energy efficiency of the building, 8 indicators are considered:



1.1.- Primary energy consumption. PEC. -

Total primary energy consumption of the building due to heating, cooling, domestic hot water, lighting and auxiliary services, obtained by direct measurement methods.

Unit: kWh/m^2. year
Limit: -&, &

1.2.- Heat Loss Coefficient. HLC. –

Total thermal losses of the building through the envelope (including thermal bridges and total air change) per unit of the temperature difference between indoor and outdoor temperatures, obtained by direct measurement methods.

Unit: kWh/m^2. year
Limit: 0, &

1.3.- Energy needs. –

Heat to be delivered to or extracted from a thermally conditioned space to maintain the intended space temperature conditions during a given period of time, obtained by means of the Energy Efficiency Certificate.

Unit: kWh/m^2. year
Limit: -&, &

1.4.- Renewable energy consumption. PERc. –

Description of the renewable energy consumption.

Unit: kWh/m^2. year
Limit: 0, &

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1.5.- Renewable energy self-sufficiency ratio. PERc/ PEC. -

Ratio between the renewable energy consumption and total primary energy consumption (PER_C/PE_C), obtained by direct measurement methods.

Unit: %
Limit: 0, 100

1.6.- Energy renewable production. PERp. –

Description of the energy renewable production.

Unit: kWh/m^2. year
Limit: 0, &

1.7.- Renewable energy self-consumption ratio. PERc/PERp. –

Ratio between the renewable energy consumption and renewable energy production of the building, obtained by direct measurement methods.

Unit: %
Limit: 0, 100

1.8.- Global Warming Potential. GWP. –

Reduction of the carbon footprint of the building achieved with its reform, obtained following the corresponding methodology. This value may be negative because the indicator may worsen the initial situation.

Unit: %
Limit: 0, 100

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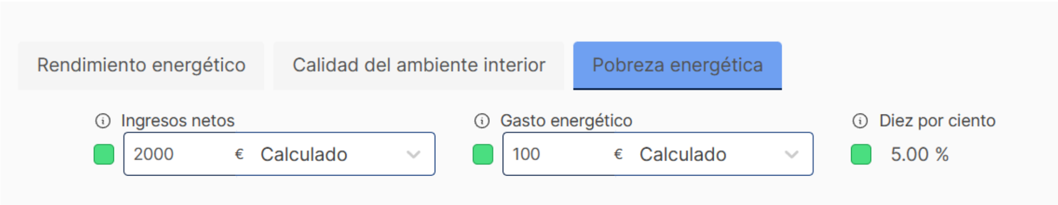
- ## III.3.- AXIS 2: Energy Poverty. -

Defined as allocating more than 10 per cent of current net household income to the energy payment of housing.



These two indicators must be defined:

2.1.- Net incomes. –

The sum of the net annual income of the household is considered. The amount to be received after the payment of taxes and social insurance.

Unit: €

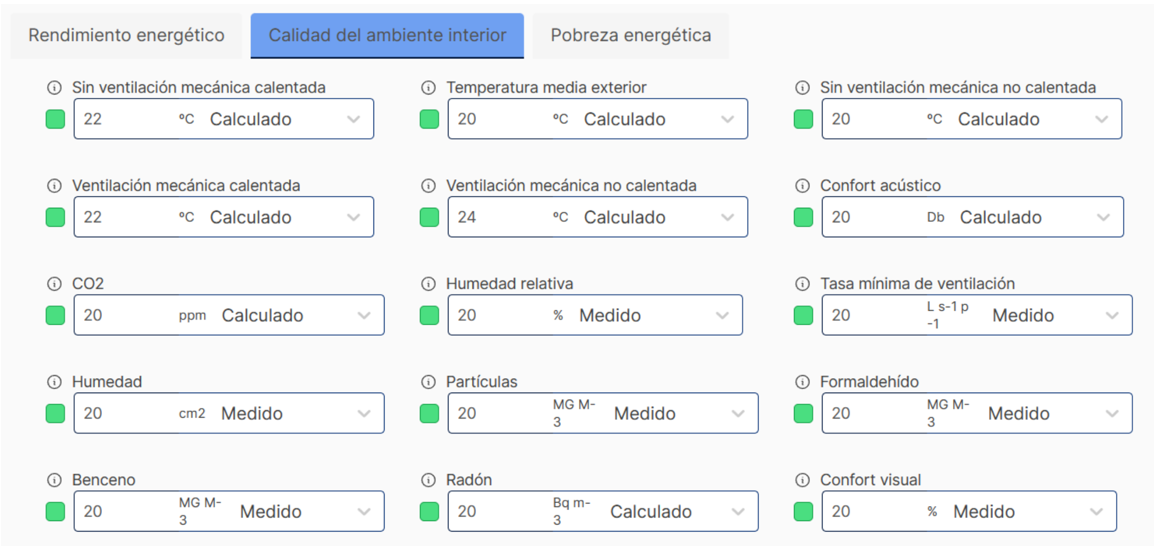
2.2.- Energy expenditure. –

Annual energy expenditure related to the energy needs of households.

Unit: €

- ## AXIS 3: Indoor Environment Quality. -

This Axis is defined by considering the following indicators:



3.1.- Thermal comfort

- No mechanical ventilation heated
- No mechanical ventilation no heated

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- Mechanical ventilation heated
- Mechanical ventilation no heated

  Unit: ºC
  Limit: -&, &

- Average outdoor temperature. –

Description of the average outdoor temperature.
Unit: ºC
Limit: 0, &

3.2.- Acoustic comfort. –

Description of the acoustic comfort.

Unit: dB
Limit: 0, &

3.3.- Indoor Air Quality

- CO_2 level. –

Description of the CO_2 level.

Unit: ppm
Limit: 0, &

- Relative humidity. –

Description of the relative humidity.

Unit: %
Limit: 0, 100

- Minimum ventilation rate. –

Description of the minimum ventilation rate.

Unit: L/p.s
Limit: -&, &

- Molds

Description of the molds area.

Unit: cm^2
Limit: 0, &

- Particles

Description of the particles floating in the air.

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Unit: µg/m³
Limit: 0, &

- Chemical (Benzene, Formaldehyde and Radon)

Description of the presence in the air.

Unit: µg/m³	Unit: Bq/m³
Limit: 0, &	Limit: 0, &

3.4.- Visual confort. –

Daytime : Percentage of time with illuminance between 300 and 500 lux at desk height.
Night-time : Percentage of the time measured with ≥100 Lux[3]

Unit: %
Limit: 0, 100.

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II.2 – Axis 1: Energy Efficiency

Energy efficiency is a key factor within the building sector due to its direct influence on the user comfort, the energy bills or even health conditions of the inhabitants. Regarding social housing dwellings, this influence is even more critical, considering the vulnerability of the users, both from an economical and health perspective.

For that reason, energy efficiency is one of the aspects that have been considered within the holistic and transversal analysis carried out in the ARCAS project

II.2.1 - Energy Efficiency Indicators

The selection of indicators has been done considering indicators used both at a regulatory and at a scientific perspective, paying attention to those indicators commonly used throughout the SUDOE territory.

Likewise, other specific scientific aspects of the ARCAS project have been considered, such as the availability to be measured and/or calculated accurately, in a reasonably straightforward and economical way, also the applicability in all the countries of the consortium, even by people external to the project.

Finally, other aspect taken into account for the selection of indicators is that each indicator must only be considered in one axis of the project. In this way, some parameters generally used to characterize comfort and energy efficiency, such as the number of hours above the comfort zone, have been dissmissed from the energy efficiency axis and have been considered in the Indoor Air Quality axis.

With these considerations explained above, the indicators finally selected for this axis of the ARCAS project have been:

- Primary energy consumption (PE_C)
- Energy needs
- Renewable energy self-sufficiency ratio (PER_C/PE_C).
- Renewable energy self-consumption ratio (PER_C/PER_P)
- Heat Loss Coefficient (HLC)
- Global Warming Potential (GWP)

Next, a detailed description of each indicator is given.

II.2.1.1 – Primary energy consumption (PEC)

It considers the total primary energy consumption, per m^2 of conditioned floor area. It is important, in order to calculate properly following indicators, that this indicator must be measured disaggregated by use (heating, cooling, DHW, lighting and auxiliaries).

How to obtain the indicator value

To determine the primary energy consumption of the building or an apartment it is necessary to measure the final energy consumption of different energy vectors: electricity, natural gas, biomass, renewable, … each of this energy vector may be used by one or several energy uses.

Once the final energy consumption of the different energy vectors is known, the primary energy factors of each type of energy are applied to determine the primary energy.

$$PE_{C,i} = FE_{C,i} \cdot \alpha_i$$

Where:

- $PE_{C,i}$ is the primary energy consumption per square meter of conditioned area $\left[\frac{kWh_{PE}}{m^2}\right]$
- $FE_{C,i}$ is the final energy consumption $\left[\frac{kWh_{FE}}{m^2}\right]$
- α_i is the primary energy factor $\left[\frac{kWh_{PEC}}{kWh_{FE}}\right]$
- and i is the energy vector.

The methodology in order to measure the final energy consumption is described in the following subsection. Regarding the primary energy factors, they are shown in Table 1.

TABLE 1 - PRIMARY ENERGY FACTORS FOR FRANCE, PORTUGAL, AND SPAIN (SOURCE IN EACH COLUMN).

Energy source	France	Portugal [1,2]	Spain [3]
LP gases	1	1	1.204
Biomass (pellets)	1	1.34	1.113
Natural Gas	1	1	1.195
Electricity	2.3	2.5	2.403

Following table shows the conversion factors for converting different units of measurement to kWh of primary energy, depending on the Lower Heating Value of the fuel used.

TABLE 2 – CONVERSION FACTORS FROM DIFFERENT UNITS OF MEASUREMENT TO PRIMARY ENERGY [4].

Fuel	Conversion factor	Units
Butane	15.17	$\frac{kWh_{PE}}{kg}$
Propane	15.53	$\frac{kWh_{PE}}{kg}$

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Biomass (in general)	4.36	$\frac{kWh_{PE}}{kg}$
Natural gas	13.87	$\frac{kWh_{PE}}{Nm^3}$

How to measure the needed variables

There are different energy sources, therefore, how to measure each one is different. We can classify them into two main groups: heat generation and electricity. The former includes heating and DHW, excluding those cases where electric radiators are used for heating or electric water heaters are used for DHW production. The latter includes the energy consumption related to cooling, lighting and auxiliaries.

For **heat generation** (non-electric), the final energy consumption can be determined in two ways:

Direct measurement. It would require the installation of a gas flow meter.

There are several types of gas meters, the most commonly installed ones are through diaphragm, rotatory and turbine gas meters [5].

The diaphragm meter is the most used type by distribution companies due to the simplicity and low cost, however wear problems, pressure losses and that they cannot indicate instantaneous flow rate value are the main disadvantages. However, due to the large number of traditional gas meters that are already installed, many manufacturers have developed an automatic meter reading (hereinafter AMR) solution. This AMR solution is used to upgrade the traditional gas flow meter to a smart flow meter.

In the case of high gas flow rates and when high-accuracy measurements are required, the rotatory meters suit well. Nevertheless, recently many static devices have been developed; one of those devices is the ultrasonic flow meter. This device shows high accuracy and it is not intrusive, which make it very suitable for use in home monitoring.

The gas flow meters are widely available in the market. Its cost varies according to measuring technology, the compatibility with AMR solutions and the measuring range. In general, the static gas flow meters are more expensive than the dynamic meters.

Once the gas flow rate has been measured, the primary energy consumption can be determined from the values in Table 2.

One of the disadvantages of this method is that in the case of combi boilers, it does not allow differentiation between consumption due to heating and DHW production.

Indirect measurement. This method consists of obtaining the energy consumption from the measurement of the useful effect ($\dot{E_u}$), according to:

$$\dot{E}_{cons} = \frac{\dot{E_u}}{\eta_{equip}}$$

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Where η is the efficiency of the equipment.

The useful effect is generally the heating of a water flow rate $\dot{Q}$, so it can be determined according to the following formula:

$$\dot{E_u} = \dot{Q} = \dot{V} * \rho * Cp * \Delta T$$

Where parameters are the following ones:

- $\dot{V}$: water flow rate [m^3/s]
- ρ: density [kg/m^3]
- Cp: specific heat [J/kg K]
- ΔT: temperature difference between supply and return [K]

There is a device called 'calorimeter' which directly provides the value of $\dot{Q}$, according to the above formula. It is composed of one flow meter and two temperature probes. Nowadays, calorimeters use an ultrasonic flow meter with no moving elements, which is able to measure water flow by measuring the time elapsed between the transmission and the reception of an ultrasonic signal. Thanks to this technology, aspects like accuracy and maintenance have improved significantly. Moreover, air bubbles that are responsible for several problems in traditional flow meters are not a problem. In the following images, the operation scheme (Figure 1) and one example of this kind of devices (Figure 2) are shown.

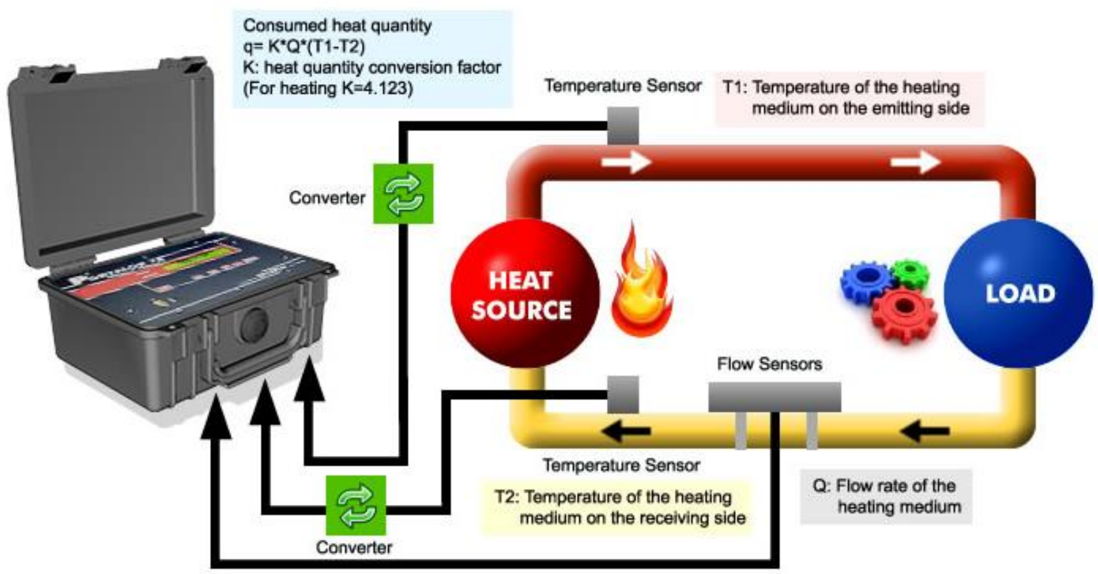

FIGURE 1 – OPERATION SCHEME OF A CALORIMETER (SOURCE: [6])

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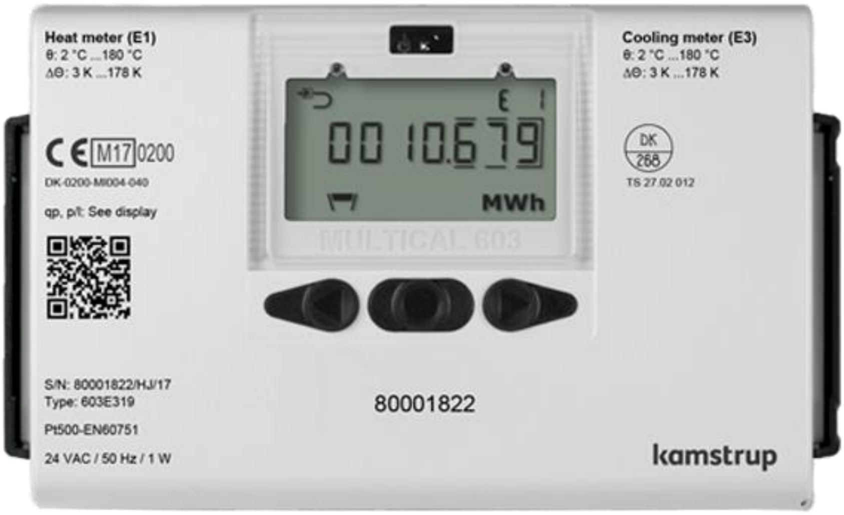

FIGURE 2 - EXAMPLE OF CALORIMETER (KAMSTRUP MULTICAL 603) (SOURCE: [7])

There are some specifications that have to be established before choosing a specific calorimeter. For example, nominal diameter, supply (electrical or battery), communication protocol, etc. are parameters that can be more or less suitable for the dwelling where they will be installed.

For the measurement of **power consumption**, there are a wide variety of sensors capable of measuring power consumption. In fact, when referring to ""smart homes"", they used to be houses equipped with this kind of sensors. If it is required to measure the final consumption of each use (lighting, auxiliaries, cooling, …), one device per each use is necessary. To obtain the total final electricity consumption, one energy module is enough.

Power meters. best known as energy modules, are used in the majority of research works related to monitoring. These energy modules can be divided into high-class modules, middle-class modules or low-class modules.

The classification depends on the capabilities of the module. In the study carried out by Dominguez et al. [8], they used high-class and middle-class modules to monitor the power consumption of several buildings. The high-class ones are capable of conducting a thorough analysis of electrical power. Taking into account the needs of the project and the difference in price, perhaps the option of a middle-class module is the most appropriate.

Traditionally, electromechanical meters have been the most widely installed in buildings. However, in recent years they have been replaced by electronic meters. The latter is more accurate and allows data to be stored and managed.

The accuracy of the electricity meters depends on the metering class, but the typical accuracy values are ranged between ±0,5% and ±2%.

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II.2.1.2 – Energy needs

This indicator considers the heat to be delivered to or extracted from a thermally conditioned space to maintain the intended space temperature conditions during a given period of time.

How to obtain the indicator value

The easiest way to obtain this indicator is using the EPC (Energy Performance Certificate) of the current building. Official certification tools simulate the behaviour of the building under standardized operational conditions. Although the simulation code and the performance characteristics of the building may be different, the fact that building certification is mandatory in France, Portugal and Spain makes it very useful within the ARCAS project in determining this indicator.

II.2.1.3 – Renewable energy self-sufficiency ratio

This indicator measures the ratio between the renewable energy consumption and total primary energy consumption (PER_C/PE_C).

The measurement of primary energy consumption has been defined in section II.2.1.1. Therefore, only the measurement of renewable energy production is explained below. how to measure the renewable energy production is needed.

As in the case of final energy, two are the main types of energy: electricity and heat. Electricity production can be measured with an energy module as it has been explained before (subsection II.2.1.1). When heat production is considered, the most common renewable production technologies are solar collector, geothermal energy and biomass. When solar collector and geothermal energy are considered, a working fluid is the energy carrier. Therefore, using a calorimeter that measures the flow rate and temperature difference of the working fluid is enough to determine the energy production of those technologies. For biomass, the consumed quantity has to be measured and then using the low heating value obtain the produced energy.

II.2.1.4 – Renewable energy self-consumption ratio

This indicator measures the ratio between the renewable energy consumption and renewable energy production (PER_C/PER_P).

The energy production and consumption measurement procedures have been defined in sections II.2.1.1 and II.2.1.3. The same devices and protocols should be used.

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II.2.1.5 – Heat Loss Coefficient (HLC)

It measures the total thermal losses of the building through the envelope (including thermal bridges and total air change) per unit of the temperature difference between indoor and outdoor temperatures.

How to obtain the indicator value

According to the definition, the HLC can be compactly defined as:

$$HLC = UA + C_v$$

Where UA is the global heat transfer of the envelope of the building [kW/ºC] and C_v is the coefficient of heat losses due to total air change (hygienic ventilation and uncontrolled air infiltration) in [kW/ºC].

In an unoccupied building, the experimental determination of the HLC can be done by the Co-heating method. This method is widely documented in the literature. For reference, the following research works are recommended [9,10,11,12].

On the other hand, in occupied buildings the determination of the UA of the building is not trivial. In fact, it is usual to experimentally determine the HLC and the coefficient C_v, and then deduce the value of UA.

In recent years, significant efforts have been made by researchers to reliably determine experimentally the HLC in occupied buildings. One of them is the one proposed by Erkoreka et al. [13]. This proposed average method has some similar characteristics regarding the mathematical estimation method used by the ISO 9869-1 method [14] for obtaining in-situ U-values of walls.

The method starts from the application of an energy balance on the dwelling. Considering the energy exchanges represented in Figure 3, the energy balance can be expressed as following equation. The complete process of obtaining this equation can be found in [15].

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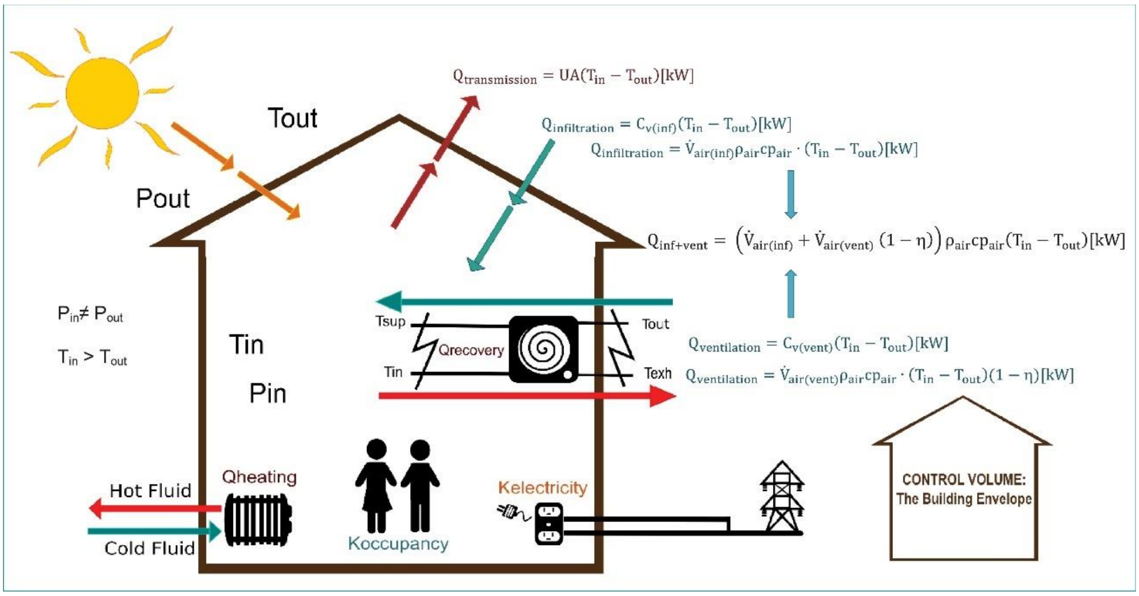

FIGURE 3 – SCHEMATIC OF ALL ENERGY AND MASS EXCHANGES THROUGH THE CONTROL VOLUME DEFINED BY THE BUILDING ENVELOPE. (SOURCE [15])

$$\frac{dU(t)}{dt} = S_a\, V_{sol}(t) + \ Q(t) + K_{electricity}(t) + \ K_{occupancy}(t) - HLC\ (T_{in} - \ T_{out})(t)$$

Where:

- *dU(t)/dt* is the energy rate being stored in the house. The internal energy of a material i (U_i) can be calculated as the product of its mass (m_i), its specific heat (c_i) and its temperature (T_i).
- S_a·is the solar aperture. A characteristic of a building, measured in square-meters of south vertical perfectly transparent surface, which lets coming in the same solar radiative energy as the whole building.
- V_{sol} is the global south vertical solar radiation. Therefore, the product $S_a \cdot V_{sol}$ represents the heat gains due to the solar radiation.
- *Q* is the total measured power input from space heating.
- $K_{electricity}$ and $K_{occupancy}$ represent the internal gains due to electricity consumption and occupants respectively. They are usually considered in a single term, called *K(t)*.
- T_{in} - T_{out} is the indoor to outdoor temperature difference.

The determination of some of these variables by instantaneous measurements, especially the accumulated energy term and solar gains in occupied buildings is very difficult. Therefore, it is necessary to perform the integrated balance over a period of time (from t_1 to t_N). Taking into account that the monitoring system performs discrete measurements every Dt, the integrals are converted into summations from k=1 (t_1) to k=N (t_N), so that the above balance can be rewritten as:

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$$HLC = \frac{\sum_{i=1}^{Z} m_i \, c_i \left(T_i(t_1) - T_i(t_N) \right) + \sum_{k=1}^{N} (Q_k + K_k + (S_a \, V_{sol})_k) \, \Delta t}{\sum_{k=1}^{N} \left(T_{in,k} - T_{out,k} \right) \Delta t}$$

Where z is the number of different materials (concrete, bricks, wood, ...) in the building under consideration.

If the monitoring period fulfils the same initial and final thermal level conditions, applying the method to periods of at least 72 h (three days), the accumulation term effect on the HLC will be negligible, and the previous equation can be simplified:

$$HLC = \frac{\sum_{k=1}^{N} (Q_k + K_k + (S_a \, V_{sol})_k)}{\sum_{k=1}^{N} \left(T_{in,k} - T_{out,k} \right)}$$

If the monitoring period, not only has the same initial and final temperature of the building, but also is cold and cloudy, the weight of the solar gains in the energy balance is small and allows making accurate estimates of the HLC, even though the solar gains are roughly calculated. In this sense, a period can be considered cold if the average indoor to outdoor temperature difference is 10 ºC or bigger.

Another advantage of considering cloudy periods is that in such situations, radiation can be considered purely diffuse. This circumstance allows any measure of global radiation, including global horizontal (H_{sol}), to be used as an estimation of V_{sol}.

In the particular case where, solar gains are considered to be zero, the value of HLC can be obtained in a simpler way according to the following equation:

$$HLC = \frac{\sum_{k=1}^{N} (Q_k + K_k + (S_a \, V_{sol})_k)}{\sum_{k=1}^{N} \left(T_{in,k} - T_{out,k} \right)}$$

To differentiate it from HLC, we will call it HLC_{simple}.

How to obtain the indicator value

According to the equations seen above (the HLC and the simple HLC), the experimental determination of the HLC requires the measurement of the following variables: T_{in} and T_{out}, Q, K, and solar radiation.

The following table (Table 3) summarizes the sensors required for the determination of the HLC, as well as the recommended uncertainties for each one.

TABLE 3 - LIST OF INPUT PARAMETERS FOR APPLYING THE AVERAGE METHOD (SOURCE: [16])

Measured parameter	Description	Sensor	Accuracy

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$T_{out,k}$ [ºC]	Outdoor temperature	Thermocouples / Pt100	± 0.5 ºC
$T_{in,k}$ [ºC]	Indoor temperature	Thermocouples / Pt100	± 0.5 ºC
Q_k [kWh]	Boiler heat output	Energy consumption device	± 2%
K_k [kWh]	Total electricity consumption	Energy consumption device	± 2%
V_{sol} [W/m^2]	Global south vertical solar radiation	Pyranometer	± 5%

General advices and recommendations

For the measurement of outdoor temperature there are different alternatives. When the objective is to measure outside conditions, a weather station is often used. In these types of stations, in addition to the outside temperature, aspects such as relative humidity, wind velocity, etc. can be measured. For the proposed indicator, it is not necessary to measure so many parameters, although it can be interesting.

Besides, when measuring air temperature, the possible effect of radiation on the sensor reading should be taken into account. This can be critical when measuring the outdoor temperature at times of high solar radiation and low air velocities. To minimise the error that this situation can create in the signal reading, it is necessary to shield the sensor and use mechanical ventilation. In the case of indoor temperature measurements, the effect is generally minor except for sensors located near sources of radiation or exposed to solar radiation through windows.

In addition to the comments already made about the need to protect temperature probes against radiation, there are several additional considerations to take into account.

Regarding the measurement of the indoor temperature, it should be measured in different rooms of the house. In order to achieve a unique temperature a non-weighted average temperature is estimated using the following formula:

$$T_{in,k} = \frac{\sum_{j=1}^{N} T_{in,j,k}}{N}$$

Where N is the total number of indoor temperature sensors installed in the house.

Regarding the measurement of solar radiation, it can be obtained from a nearby meteorological station. Besides, if the monitoring period allows it (cold and cloudy days), the global horizontal solar radiation can be used (H_{sol}).

II.2.1.6 – Global Warming Potential (GWP)

The GWP measures the heat absorbed by any greenhouse gas in the atmosphere over a given period of time, relative to the heat that would be absorbed by the same mass of carbon dioxide (CO_2). Since CO_2 is the reference gas, its GWP is 1. At first, the GWP was defined to classify different gases. However, its use has been extrapolated to materials and processes. Thanks to this indicator, we are capable to know the GWP of a particular material or process, measuring it in [kg CO_2 eq/m^2].

Regarding the building as a whole, it is common to talk about the carbon footprint of a building. It is measured according to the equivalent CO_2 emissions in [kg $CO_{2\ eq}$] or also [kg $CO_{2\ eq}$/m^2]. It quantifies the total amount of greenhouse gas emissions for the entire life cycle of the building. The life cycle is usually set at 50 years, but since the ARCAS tool is though for the renovation of buildings, the life cycle in this case is set in 30 years, which is a coherent lifetime for a renovated building.

The calculation methodology of the GWP indicator within the life cycle of a renovated building is complex and thorough. The tools and the data needed for a comprehensive calculation of the indicator require a certain level of experience. The user of the ARCAS tool is free to follow the methodology provided by standard EN 15978 [17] in order to calculate the GWP indicator values needed. However, in this guidebook a simplified methodology to calculate the GWP needed for the ARCAS tool indicator is given. This simplified methodology is in accordance with suggestions given by the *Level(s)* project [18].

Regarding the ARCAS tool, the aim of the GWP indicator is to analyze the reduction potential of decreasing the GWP with the renovation of the building. Thus, two values for the GWP are needed. The GWP of the building at its current state, and the GWP of the building once renovated, both at a life cycle of 30 years.

How to obtain the indicator values

Since the aim of this indicator is to compare the GWP of the building without renovation, and the GWP potential once the building is renovated, two values for the GWP will be needed by the ARCAS tool:

- GWP_0: GWP value [Tn$CO_{2\ eq}$ in 30 years] of the current building, without renovation.
- GWP_R: GWP value [Tn$CO_{2\ eq}$ in 30 years] of the renovated building.

Thus, the indicator value for the ARCAS project will be derived as follows:

$$GWP_{ARCAS}(\%) = \frac{GWP_0 - GWP_R}{GWP_0} \cdot 100$$

With this, the GWP_{ARCAS} indicator measures the potential of reduction of GHG once the building is renovated, over the 30 years life cycle of the renovated building.

How to calculate the needed values

As explained before, two values of the GWP are needed in order to obtain the GWP ARCAS indicator, the GWP of the building before the renovation and the GWP of the building after the renovation. Next, the methodology to calculate these values is given, but before, it must be taken into account that for both values, the first year of calculations is the year of the renovation. That is to say, the embodied energy of the current building, or the building before its renovation, is avoided. Following figure shows the life cycle stages from EN 15804:2012 [19] related to the refurbishment process.

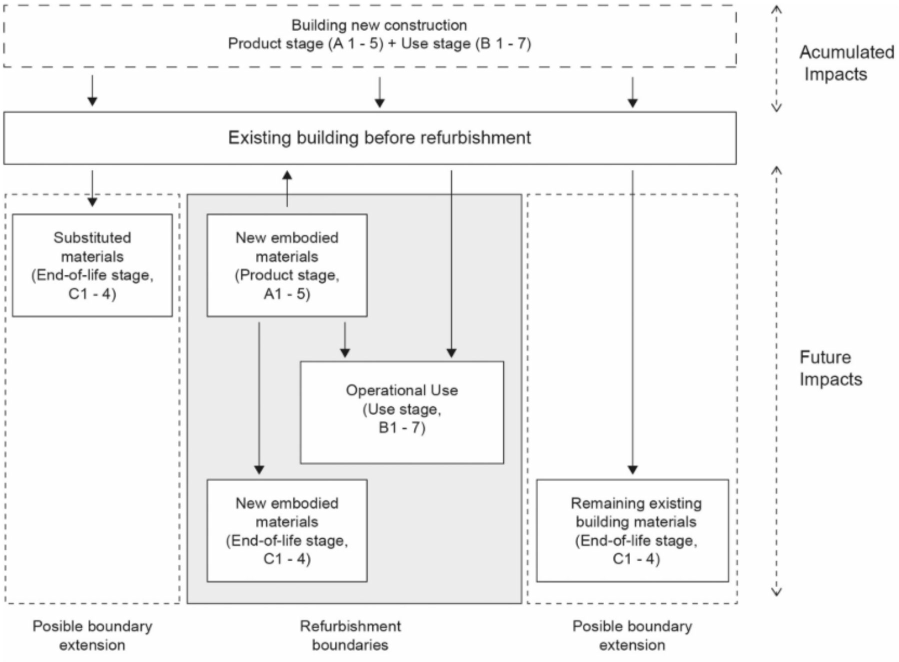

FIGURE 4 – BUILDING REFURBISHMENT BOUNDARIES (SOURCE: [20])

Thus, the values for the GWP_0 and the GWP_R may be derived as follows.

- **GWP_0: GWP value [$TnCO_{2\,eq}$ in 30 years] of the current building, without renovation.**

During the life cycle of the current building, the processes related with GHG emissions are the use stages B1-B7, without the renovation. The main impact is due to the B1-Use, that is to say, emissions related with the HVACs systems. Thus, if the $NRPE_C$ [kWh/y] of the building is known, taking into account ""n"" types of energy vector, the GWP_0 may be derived as follows:

$$GWP_0 = \frac{1}{1000} \cdot \left(30 \cdot \sum_{i=1}^{n} NRPE_{C,i} \cdot \beta_i \right)$$

Where:

- $NRPE_{C,i}$ is the Non-Renewable Primary Energy Consumption of the current building for each energy vector ""i"", e.g.: natural gas, electricity, biomass, etc. [kWh/y].
- β_i is the Conversion Factor from energy to CO_2 emissions for each energy vector, according to the energy mix of each country. [$kgCO_{2\,eq}$/kWh].

The $NRPE_C$ of the current building may be found at the EPC of the building, or it may be derived using the Primary energy consumption (PE_C) and the Renewable energy self-sufficiency ratio (PER_C/PE_C), explained previously in this document. Thus, the current $NRPE_C$ of the building may be calculated as:

$$NRPE_C = \left(1 - \frac{PER_c}{PE_c}\right) \cdot PE_c$$

- **GWP_R: GWP value [$TnCO_{2\,eq}$ in 30 years] of the renovated building.**

The calculation of the GWP_R differs from the calculation from GWP_0 in that the GHG related to the materials and systems used for the renovation process are considered. Besides, the $NRPE_C$ refers to the energy consumption of the building, which must be, logically, less than the $NRPE_C$ of the building at the current state.

The GWP of the materials and systems used for the renovation may be calculated using the EPD (Environmental Product Declaration) of those materials or products, or any other methodology or database. It must be noted that, for the GWP_0, the C1-4 stages, and the D stage of the life cycle assessment are avoided in order to simplify the methodology. Thus, the GWP of each renovation material or system must only consider the A1-3 and the A4-5 stages.

With this, the GWP_R of the renovated building, considering ""m"" renovation measures, may be derived as follows:

$$GWP_R = \frac{1}{1000} \cdot \left(\sum_{i=1}^{m} GWP_{RM,i} + 30 \cdot \sum_{i=1}^{n} NRPE'_{C,i} \cdot \beta_i \right)$$

Where:

- $GWP_{RM,i}$ is the GWP of the Renovation Measure ""i"", obtained using an EPD or any other suitable methodology [$kgCO_{2\,eq}$].
- $NRPE'_{C,i}$ is the Non-Renewable Primary Energy Consumption of the renovated building of energy vector ""i"", e.g.: natural gas, electricity, biomass, etc. [kWh/y].
- β_i is the Conversion Factor from energy to CO_2 emissions for each energy vector, according to the energy mix of each country. [$kgCO_{2\,eq}$/kWh]

In this case, the $'NRPE'_C$ of the renovated building must be obtained using any suitable simulation or certification tool, applying the renovation measures considered for the building.

II.2.2 – Relative weights

In order to obtain a single score value in the energy efficiency category, a relative weight has been established for each of the indicators described above.

These relative weights have been agreed considering the interrelationships that some indicators have with each other (e.g. a low value of energy needs will in turn imply a lower value of energy consumption).

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The following table shows the relative weights of each indicator in the Energy Efficiency category.

TABLE 4 -RELATIVE WEIGHTS OF ENERGY EFFICIENCY INDICATORS

Indicator	Weight (%)
PE_C	20
Energy needs	30
PER_C/PE_C	15
PER_C/PER_P)	10
HLC	10
GWP	15

II.2.3 – Categories

When considering each indicator in the ARCAS tool, 4 categories have been established, with category IV being the worst and category I the best. Specifically for the proposed indicators in the field of energy efficiency, the ranges within each category are shown below.

TABLE 5 – ENERGY EFFICIENCY INDICATORS CATEGORIES

Category	I	II	III	IV
PE_C [kWh/m²·y]	< 85	[85, 125)	[125,165)	[165,205)
Energy needs [kWh/m²·y]	< 18	[18, 50)	[50, 85)	[85, 115)
PER_C/PE_C [%]	≥ 60	[40, 60)	[20, 40)	[0, 20)
PER_C/PER_P) [%]	< 40	[40, 60)	[60, 80)	[80, 100)
HLC [W/m²·K]	< 2.4	[2.4, 3.1)	[3.1, 4.0)	[4.0, 4.7)
GWP [%]	≥ 30	[20, 30)	[10, 20)	[0, 10)

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II.3 – Axis 2: Energy Poverty

Energy poverty is a growing problem in Europe. It is a multidimensional and complex societal issue closely related to households' inability to meet their energy needs due to low income, high energy expenses, and poor energy efficiency in buildings. It is estimated that about 36 million people are unable to keep their homes adequately warm in the European territory [1]. It has strong economic, political, social, and health implications, and there is evidence that it is likely to increase during financial or energy crises as Europe is facing now. Tackling the problem is, therefore, urgent and relevant for Europe.

The definition proposed for the energy poverty assessment in the ARCAS project follows the EU Energy Poverty Observatory (EPOV) definition, where energy poverty can be defined as the "inability of a household to access socially and materially necessitated levels of energy services in the home" [2].

II.3.1 - Social Quality and Energy Poverty Indicators

To be considered in the ARCAS methodology, indicators must meet several requirements. One of the most important is the need for easy and affordable but rigorous measurability for the parameters composing the indicator. Besides, the indicators must be compatible in different national contexts within the scope of the project and flexible to use both direct measurements and calculations from numerical simulations.

The analysis to be performed in the ARCAS project is focused on the household and, ultimately, at the neighbourhood level. Therefore, both the calculation methods and data sources should be consistent with that objective. In this context, the lack of economic availability to pay for energy services is a characteristic determinant factor.

Within the ARCAS project, the 10% indicator was selected to evaluate how the buildings' performance can support energy poverty alleviation, which is an expenditure-based indicator that provides a simplistic perspective of the problem but gives a very objective overview of an energy poverty situation.

II.3.1.1 – 10% Indicator

The 10% indicator establishes a direct relationship between the net income and the energy expenditure of a household. It uses the following formulation to assess energy poverty situations (Equation 1).

$$10\%\ Indicator = {household\ energy\ expenditure}/{household\ net\ income} \qquad (1)$$

Criterion to assess whether a household is in energy poverty:
10% Indicator > 10%
The 10% indicator should be calculated using the following rationale:

1. Estimation of the net income for the household;

2. Estimation of the energy expenditure;

3. Generation of the ratio between the two previous parameters.

To obtain the **net income**, it is recommended that at least the occupational status of the households is known: the number of people employed, unemployed, retired, with social benefits, etc.. Since the ARCAS project focuses on low-income contexts such as social housing neighbourhoods, it is proposed to adopt the respective national minimum values foreseen for these occupational statuses, multiplied by the number of people classified in each. Alternatively, if regional or local specificities are sought to be important for the assessment, direct consultation can be used. Regarding the net income, it should be estimated using Equation 2.

$Net\ Income =$ *(Non-taxable income + Taxable income) – (National insurance (or Social security) payable + Income tax payable)* (2)

The data sources indicated in **¡Error! No se encuentra el origen de la referencia.** can be consulted regarding incomes in the different national contexts.

TABLE 6 – DATA SOURCES FOR NATIONAL INCOMES IN THE DIFFERENT COUNTRIES BEING ADDRESSED IN THE ARCAS PROJECT

National Context	Data Source for Income
France	www.insee.fr, www.onpe.org
Portugal	www.pordata.pt
Spain	www.mites.gob.es

As for the most European countries the share of expenditure exclusively used for heating is not available [3], the **energy expenditure** should be estimated, when possible, using the energy needs stated in the Energy Performance Certificates (EPC) of the Building. This method of obtaining the energy needs accommodates the local specificities of the three participating countries, as it follows the calculation methods defined in the legislation. If an EPC is not available, the energy needs should be calculated using the same methodology and procedures as the ones foreseen by each country's legislation, which can be using dynamic or steady-state calculations for simulating the energy performance of the building.

The energy performance should relate to the energy demand associated with the typical use of the building, which includes energy used for space heating and cooling, domestic hot water, lighting, and ventilation [2], taking as a reference the standardized temperature threshold defined in each national thermal regulation. The numerical model used should consider, inter alia, the physical characteristics of the buildings (e.g., thermal transmittance coefficient of the envelope), internal gains of the dwelling, and the type of heating and cooling system used.

After the estimation of the energy needs, the energy expenditure should be calculated taking into account the different energy vectors in use in the building and the current prices of the different energy carriers for each national context, including applicable fees.

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II.3.2 – Relative weights

Since a single indicator is used to represent the energy poverty in the ARCAS project, the 10% indicator has a relative weight of 100%, as shown in Table 7.

TABLE 7 – RELATIVE WEIGHTS OF ENERGY POVERTY INDICATORS

Indicator	Weight (%)
10% indicator	100

II.3.3 – Categories

Considering that the energy poverty indicator selected for the project predicts that the ratio between net income and energy expenditure should not exceed 10%, this is the limit and the optimal value of Category I. This and the following categories can be seen in Table 8.

TABLE 8 – 10% INDICATOR CATEGORIES

Category	I	II	III	IV
10% indicator	≤ 10%	(10%, 15%]	(15%,20%]	> 20%

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II.4 – Axis 3 : Indoor Air Quality

II.4.1 – TAIL tool (ALDREN)

Implemented during the ALDREN project in 2017, the TAIL index is an index that measures different elements of indoor environmental quality in a building. It consists of four different domains, which define the acronym of the index:

- T : Thermic Confort
- A : Acoustic Confort
- I : Indoor Air Quality
- L : Luminous Confort

For these four areas we will assign them a quality category, the latter will be determined in relation to various factors predetermined according to the measures. These 4 levels will be represented by Roman numerals (which can easily be replaced by letters ABCD) So we have the following 4 categories:

- I : Good Quality
- II : Normal Quality
- III : Moderate Quality
- IV : Poor Quality

A Category I building means that the environment is good or even optimal. The environment is healthy and there will be nothing to change in the future

A Category II building means that the environment is normal, the environment is quite liveable but it could be improved

A category III building has a moderate environment, the building remains viable but with a certain risk all the same present.

A category IV building shows poor environment, in the long term this can lead to serious sequelae on the health of users, so it must be quickly remedied.

We will choose the most unfavourable case of the 4

III.4.2 – Measurement period

According the proposal v5, 02/04/2021 by Wenjuan Wei, Corinne Mandin and Pawel Wargocki.

The TAIL indicators should be measured in dwellings during the day and night, and the TAIL level of a dwelling should be calculated using both daytime and nighttime values. This is due to the consideration that the occupants' health and well-being in dwellings should be evaluated on the 24-hour basis every day. Table 1 shows the measurement locations. For carbon dioxide, noise and illuminance evaluations, the daytime data in the living-room and

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the nighttime data in the main bedroom should be assessed separately. For the other indicators, the daytime and nighttime data are assessed together.

The measurement protocols of TAIL indicators for dwellings should be consistent with those for offices and hotels (ALDREN-TAIL protocol).

Table 9 – Measurements of TAIL indicators in dwellings

TAIL component	Indicator	Living-room	Main bedroom
Thermal environment (T)	Air temperature	Mandatory	Mandatory
Acoustic environment (A)	Sound pressure level	Optional	Mandatory
Indoor air quality (I)	Ventilation rate	At all air inlet if presence of a mechanical ventilation system	
	Carbon dioxide concentration	Optional	Mandatory
	Formaldehyde concentration	Optional	Mandatory
	Benzene concentration	Optional	Mandatory
	Particle (PM2.5) concentration	Mandatory	Optional
	Radon concentration	Optional	Mandatory
	Air relative humidity	Mandatory	Mandatory
	Visible mold area	Mandatory	Mandatory
Visual (luminous) environment (L)	Illuminance	Mandatory	Optional[1]
	Daylight factor	Mandatory	Mandatory

[1] Optional due to technical limitation

II.4.3 – Thermal Environment

For this section we note the temperature inside the different rooms of the dwelling. Temperatures are measured over a week or so. Then we are careful if the housing is in a heating period or not.

The ranges of the indoor air temperature (Table 10) are determined according to the standard EN 16798 for residential buildings in living spaces. Compared to TAIL for offices and hotels, the ranges for dwellings during the heating season have been changed.

Table 10 – Ranges of the indoor air temperature

Quality of the thermal environment (T)	Buildings with mechanical cooling		Buildings without mechanical cooling	
	Heating season[1]	Non-heating[2] (cooling) season	Heating season[1]	Non-heating[3,4] (cooling season)
Green	23±2 °C	24.5±1 °C	23±2 °C	upper limit $0.33\Theta_{rm}+18.8+2$ °C lower limit $0.33\Theta_{rm}+18.8-3$ °C
Yellow	22.5±2.5 °C	24.5±1.5 °C	22.5±2.5 °C	upper limit $0.33\Theta_{rm}+18.8+3$ °C lower limit $0.33\Theta_{rm}+18.8-4$ °C
Orange	21.5±3.5 °C	24.5±2.5 °C	21.5±3.5 °C	upper limit $0.33\Theta_{rm}+18.8+4$ °C lower limit $0.33\Theta_{rm}+18.8-5$ °C
Red	If other quality levels cannot be achieved		If other quality levels cannot be achieved	

[1] Assuming clo 1.0, sedentary activity and RH=50%
[2] Assuming clo = 0.5, sedentary activity and RH=50%
[3] Summer and shoulder seasons; Θrm is running mean outdoor temperature that can be calculated as follows :
$\Theta_{rm} = (1-\alpha)\{\Theta_{ed-1} + \alpha\,\Theta_{ed-2} + \alpha 2\,\Theta_{ed-3}\}$

where:

Θ_{rm} = outdoor running mean temperature for the considered day (°C)
Θ_{ed-1} = daily mean outdoor air temperature for the previous day α = constant between 0 and 1 (recommended value is 0.8)
Θ_{ed-i} = daily mean outdoor air temperature for the i-th previous day

Alternatively, using the following approximate formula (when records of daily running mean outdoor temperature are not available):

$Q_m = (Q_{ed-1} + 0.8\,Q_{ed-2} + 0.6\,Q_{ed-3} + 0.5\,Q_{ed-4} + 0.4\,Q_{ed-5} + 0.3\,Q_{ed-6} + 0.2\,Q_{ed-7})/3.8$

[4] Daily mean outdoor air temperature for previous day obtained from measurements or the nearby meteorological station.

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II.4.4 – Acoustic Environment

Acoustic comfort is a very important element in buildings, indeed too much exposure to noise can lead to irreversible sequelae (deafness, tinnitus, hyperacusis ...).

For this we will carry out a measurement of the indoor ambiant noise as well as the external ambient noise. The sound level will be measured for each frequency band (from 63 to 8000 Hz). This will then allow us to calculate the overall isolation of the building from the outside.

The categories are as follows:

Table 11 – Ranges of the sound pressure level

Quality of the acoustic environment (A)	Living-room, daytime	Bedroom, nighttime
Green	≤ 30 dB(A)	≤ 25 dB(A)
Yellow	≤ 35 dB(A)	≤ 30 dB(A)
Orange	≤ 40 dB(A)	≤ 35 dB(A)
Red	If other quality levels cannot be achieved	If other quality levels cannot be achieved

II.4.5 – Indoor Air Quality

Indoor Air Quality is an essential element for the occupants of the building, it depends on many criteria :

- CO_2 Concentration
- Relative Humidity
- Ventilation flow
- The presence of mold
- VOC Concentration
- Particulate matter concentration ($PM_{2.5}$)

Compared to TAIL for offices and hotels, the ranges of ventilation rate have been changed using the default design ventilation air flow rates for residential buildings according to EN 16798, while the ranges of the other IAQ indicators have not been changed (Table 4). Concerning the relative humidity, the ranges for dwellings are consistent with those for hotels to reduce the risks of house dust mites. Concerning the carbon dioxide, the living-room and bedroom have different ranges.

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Table 4 – Ranges of the indoor air quality indicators

Quality of indoor air quality (I)	Green	Yellow	Orange	Red
Carbon dioxide (concentration above outdoors)[1,2]	≤ 550 ppm (living-room) ≤ 380 ppm (bedroom)	≤ 800 ppm (living-room) ≤ 550 ppm (bedroom)	≤ 1350 ppm (living- room) ≤ 950 ppm (bedroom)	If other quality levels cannot be achieved
Ventilation rate[3,7]	ACH ≥ 0.7 h^{-1}	ACH ≥0.6 h^{-1}	ACH ≥ 0.5 h^{-1}	If other quality levels cannot be achieved
Relative humidity[2,4,5]	≥ 30% and ≤ 50%	≥ 25% and ≤ 60%	≥ 20% and ≤ 60%	If other quality levels cannot be achieved
Visible mold[6,7]	No visible mold	Minor moisture damage, minor areas with visible mold (< 400 cm^2)	Damaged interior structural component, larger areas with visible mold (< 2500 cm^2)	Large areas with visible mold ≥2500 cm^2)
Benzene[7]	< 2 μg/m^3	≥ 2 μg/m^3	no criteria	≥ 5 μg/m^3
Formaldehyde[7]	< 30 μg/m^3	≥ 30 μg/m^3	no criteria	≥ 100 μg/m^3
Particles $PM_{2.5}$ (gravimetric)[7]	< 10 μg/m^3	≥ 10 μg/m^3	no criteria	≥ 25 μg/m^3
Particles $PM_{2.5}$ (optical)[7]	< 10 μg/m^3	≥ 10 μg/m^3	no criteria	≥ 25 μg/m^3
Radon[7]	< 100 Bq/m^3	≥ 100 Bq/m^3	no criteria	≥ 300 Bq/m^3

[1] Outdoor CO_2 should be measured or assumed using https://www.co2.earth/.

[2] To be classified in each quality level, the measurements shall not exceed the range defined by the indicated quality level and the subsequent quality level by no more than 5% of the time, and the range defined by the subsequent quality level and the next lower quality level by no more than 1% of the time.

[3] Criteria based on pre-defined supply ventilation air flow rates for residential buildings according to EN 16798-1, assuming that air is supplied in living rooms and extracted from wet rooms.

[4] The levels match EN 16798-1 regarding humidification requirements.

[5] The higher levels selected to avoid house dust mite infestation (survival and reproduction).

[6] According to the Nordic classification system and Level(s); observations in the instrumented rooms should be supplemented by locations where the risk of mold is likely (e.g., using simulations of surface relative humidity).

[7] The permissible levels that cannot be exceeded.

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II.4.6 – Luminous environment

For the well-being of users, it is necessary to ensure a good natural illumination of the housing, too low lighting will result in the use of artificial lighting and therefore an additional energy consumption. While too much illumination will create glare.

In addition, beyond the optimization of the illumination there will also be elements to take into account such as the orientation of the building, the inclination of the windows, the type of glazing, the presence of cap or side cheeks, the arrangement of the furniture inside, etc.

In our case we will be mainly interested in the percentage of time where the illumination is located in a given value range. In our case it will be between 300 and 500 lux during the day and 100 lux during night.

Table 5. Ranges of the visual environmental indicators

Quality of the luminous environment (L)	Daytime		Nighttime
	Daylight factor[1]	% of the time with measured illuminance between 300 and 500 Lux[2]	% of the time measured with≥100 Lux[3]
Green	≥5.0%	≥60% and ≤100%	0 %
Yellow	≥3.3%	≥40% and <60%	>0 % to ≤50 %
Orange	≥2.0%	≥10% and <40%	>50 % to ≤90 %
Red	If other quality levels cannot be achieved	If other quality levels cannot be achieved	If other quality levels cannot be achieved

[1] The lowest daylight factor to reach respectively ≥750 Lux, ≥500 Lux, ≥300 Lux and ≥100 Lux, according to EN 17037 for Brussel.

[2] Following the requirements of the HQE green building certification scheme (HQE, 2019).

[3] Following the requirements of CASBEE (2014); CASBEE requirement is only for the illuminance level and not for the frequency of occurrence.

II.4.7 – Calculation Method

The TAIL index is calculated using an Excel spreadsheet. The latter is divided into several worksheets (one for each item presented before). Usage is simple it is enough to enter the measured data in the cells provided for this purpose. (It should be noted that for some domains it is necessary to enter a series of values over a week, while in others a value is sufficient). Then macros were programmed to define the measured category based on the input data. Finally, after being defined on the 4 domains, the categories will be carried over to the first worksheet.

Thus, the most unfavourable category will be selected for the overall TAIL index.

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II.5 – Diagnostic assessment tools

II.5.1 - Climatological Indicators

ARCAS Climate and Air Quality Map has been developed with climate and air quality indicators.

The map has been elaborated in collaboration with the Spanish Meteorological Agency (AEMET) and Predictia Intelligent Data Solutions SL.

The availability of climatic indicators for the ARCAS area is subject to the density of monitoring stations, their availability, and the frequency and temporal continuity of the measurements.

Over the last few years, the generalization of meteorological sensors in urban areas (both in private buildings and in public institutions), communication networks (roads), and the public availability of the observations obtained through social networks (in specialized occasions in the diffusion of meteorological observations), makes us consider that we have a great density of observations of atmospheric variables. This being true, it cannot be directly deduced that we have the same density and availability of climate data.

Climate values are observations over a sufficiently long-time window that must meet some conditions. The observations must be continuous and homogeneous for these values to be reliable and representative. In other words, there have been no changes in the observation methods –instruments, schedules, etc...– or in the location of the station or its surroundings. In addition, for a large area such as the ARCAS zone, the observations must also be homogeneous in space. It means that they must constitute an observation network, with the same observation conditions and common characteristics of instruments and methods employed.

By imposing these conditions on the observations of atmospheric variables, the availability of quality climatic values is reduced. The flood of observations that are disseminated through social networks does not meet – in most cases – homogeneity criteria in relation to the observation systems and, those which could meet it, don't have enough historical data to generate climate series or indicators.

In general, it is considered that a climatic variable is well described with thirty years of observation. During that period a large enough sample that reflects most of the natural variability of the chosen parameters is collected. This allows the calculation of mean, extreme values; and other moments of the distribution that will remain reasonably stable. The last standard period chosen by the World Meteorological Organization (WMO) for the climatic characterization of an area corresponds to the 1981-2010 period, which for us, and hereafter, will be the reference period.

II.5.1.1 – Identification of variables and indicators

In accordance with the requirements of ARCAS and in relation to the axes of Energy and Air Quality, a set of variables of interest have been identified to achieve the objectives that have been set. Some of them coincide with those detailed in this same document, in order to respond to the regulatory needs mentioned therein. In addition, other variables are proposed that are considered useful to calculate energy consumption in more detail.

air temperature: meteorologically speaking, it is considered as the temperature read on a thermometer exposed to the air, protected from direct solar radiation at 1.5 m height from the ground. Climatologically speaking, it is described by the monthly and annual averages of the daily maximum and minimum temperatures corresponding to the same reference period. The behaviour of temperature is well known, both in its diurnal and annual cycles, as well as its close correlation with altitude. These characteristics of the variable –its continuous distribution in time and space, as well as its correlation with altitude– facilitate the construction of regular grids through spatial interpolation of the data. The final resolution of these grids is limited by the density of observations and the information (correlation) that each observation provides about the spatial environment surrounding it. This marks an effective resolution from which the interpolation algorithm will not provide new information no matter how much it tries to force it to reach high resolutions.

Rain: It is the liquid or solid product of the condensation of water vapor that falls from the clouds or from the air and is deposited on the ground. It includes rain, hail, snow, and some deposits such as dew drops, and other deposits less frequent. The total amount of rain that reaches the ground in a given period is expressed in mm of height (or vertical depth of water) that would cover a horizontal fraction of the Earth's surface. Expressing precipitation in mm is equivalent to expressing it in volume divided by area (*eg* litres per square meter). The general problem of representativeness is particularly difficult in the measurement of rain. Rain measurements are especially sensitive to orientation, wind, and topography. The average monthly and annual rainfall in the reference period will be collected.

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Air humidity: The moisture content of the air is the amount of water vapor that is dissolved in a given amount of dry air. It is expressed in different ways, although the most common is to express it as Relative Humidity (RH) or according to the Dew-Point Temperature (Td). In practice, the two variables are interchangeable, with the appropriate transformations. The moisture content of the air is an important thermal regulator. If the humidity is low, the air has a greater capacity for evaporation than if the humidity is high. The process by which liquid water changes phase and becomes water vapor absorbs energy from the environment, which reduces its temperature. The HR is the fraction of humidity that the air mass contains with respect to the maximum that its temperature and pressure can contain and is expressed as a percentage. The 0% value is very rare in nature, virtually non-existent in our environment, while 100% is reached when the air becomes saturated with humidity, condensation occurs, and water appears again in a liquid state (as fog, clouds, condensation on cold surfaces, dew, frost…).

The dew point, Td, expresses the temperature at which, upon cooling, the air becomes saturated with a given moisture content. It is expressed in degrees, and is always, necessarily, lower than the air temperature. The temperature of the air and the dew point equalize when the air reaches saturation.

The close relationship between temperature and humidity determines the distribution of RH throughout the day. At dawn, with the lowest temperatures of the day, very high humidity values are recorded, while in the hours around the maximum temperature, the RH values are the lowest of the day. In the ARCAS area, with a distinctly maritime climate, the moisture content is generally high, the daily variations are small, and the variable is distributed in space with little variations. The variable is described through the average monthly and annual HR.

In chapter 4 of the WMO publication nº8 - Guide to Meteorological Observation Instruments and Methods-[1], there is a wide list of concepts related to the moisture content of the air, and how to evaluate them.

Wind: The surface wind speed module measured at a height of 10 meters above the ground will be included. The velocity module is related to the infiltration capacity of the air through cracks, fissures, coatings, enclosures, structures, etc. This variable can be formulated as the monthly or annual speed average, expressed in km/h; or it can be presented as the average monthly or annual path of the wind and expressed in km.

Wind speed increases considerably with height, especially over hilly terrain. For this reason, the standard height of 10 m above the ground for the installation of measuring instruments has been defined. In theory, the optimal location to carry out observations of this variable is a place where the observed wind is representative of the existing one over an area of at least a few kilometers in length. On uneven terrain, with both natural and artificial obstacles or accidents, the speed and direction of the wind vary considerably in space. Also, the great temporary fluctuation of the variable must be considered, with gusts of different duration and speeds that follow one another without interruption, and that generates what is called gustiness. For these two reasons –the representative location of a few km and the great variability of the wind with the irregularities of the terrain and the presence of obstacles– the

[1] http://measuringtheweather.com/wp-content/uploads/2012/05/Chapter-16-Metadata-from-WMO-2008-Observation-methods-CIMO-Guide-7th-Edition-2008.pdf

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spatial resolution that can be expected from the wind observations is not as detailed as that of other variables that can be expected; they are more evenly distributed, with less variation in space and time. Therefore, we understand that the variable will be well described with the average monthly and annual values of the accumulated route, or of the average speed.

Insolation and radiation: insolation refers to the time that the solar disk shines against the background of the sky, which causes shadows behind illuminated objects. Although it is an easy phenomenon to observe, insolation has more to do with visible radiation than energy radiated at other wavelengths, although both aspects are inseparable. In the research of a reference value that would allow the measurement of insolation to be homogenized, the WMO established the following definition[2]*: the insolation duration corresponding to a given period is defined as the sum of the sub-periods during which the direct solar irradiance exceeds 120* Wm^{-2}. Obviously, it is expressed in hours, and it is an additive quantity, resulting in climatological terms in hours of monthly or annual sunshine.

The duration of insolation has a good correlation with the global solar radiation. It is also related, inversely, to the amount of cloudiness, although to a lesser degree because it depends on the type and height of the prevailing clouds. For example, it is not true when the cloud cover is high and thin, translucent, or when the clouds do not hide the sun. Currently, the observation network of automatic weather stations measures the duration of the sun with a pyrheliometer that records the transition from direct solar irradiance to the threshold of Wm^{-2}.

Variables related to radiation are classified, according to their origin, into two groups: solar radiation and terrestrial radiation. In this context, radiation can express a process or a set of variables or magnitudes. In any case, the radiation fluxes received and emitted by the terrestrial surface constitute some of the most important variables for the thermal balance of any point on its terrestrial surface or in the atmosphere.

Solar radiation is the electromagnetic energy emitted by the sun. Most of it, 97%, is in the emission range called shortwave, between 290 and 3000 nanometers (nm). A part of this energy passes through the atmosphere and reaches the earth's surface, while another part is dispersed or absorbed by different particles and atmospheric components (gaseous molecules, aerosols, water drops, ice crystals...).

Terrestrial radiation is long-wave electromagnetic energy emitted by the Earth's surface and by gases, aerosols, and clouds in the atmosphere; it is also partially absorbed in the atmosphere. For a temperature of 300 K (about 27 ºC), 99.99 percent of the energy of terrestrial radiation has a wavelength greater than 3.000 nm, and around 99 percent, is greater than 5.000 nm. As the spectral distributions of solar and terrestrial radiation hardly overlap, it is common to treat both measurements and calculations separately. In meteorology, the sum of these two types of radiation is called total radiation.

Global celestial radiation is defined as solar radiation received on a horizontal surface and includes radiation directly from the solar disk, as well as diffuse celestial radiation scattered through the atmosphere.

[2] Recommendation 16 (CIMO-X), formulated by the Commission on Instruments and Observation Methods at its tenth meeting (1989)

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The total radiation covers both the short wavelengths of solar origin (between 300 and 3000 nm) and the longer wavelengths of terrestrial and atmospheric origin (between 3000 and 100.000 nm). The instruments measure the ascending or descending components of the radiation flux and that, used in pairs, allows measuring the differences between both components, which represent the net radiation.

Air quality variables: Variables derived from the following pollutants related to air quality have been considered:

- $PM_{2.5}$: Particulate Matter 2.5 are very small airborne particles that have a diameter of less than 2.5 microns. Particulate matter includes organic chemicals, dust, soot, and metals. Specifically, $PM_{2.5}$ can come from all kinds of combustion, such as cars, trucks, factories, wood burning, agricultural burning, and other activities. They are considered as atmospheric pollutants due to their harmful effects on health.
- CO_2 : Carbon dioxide
- CO : Carbon monoxide

II.5.1.2- Spatial and temporal resolution. -

In the previous paragraphs, the conditions for the observation of the different meteorological variables have been described as well as the conditions that they must be met to adequately describe the climatological conditions of a place, the need for them to have been taken with similar measurement systems, in the same periods of time, with the same methods, etc. Mention has also been made of the need for the time frame of the observations to be compatible, and we have chosen a reference period (thirty years from 1981 to 2010) from which we will obtain the data whenever possible.

We also have seen the reasons why the measurements of different variables have different spatial representations, in many cases for reasons that are intrinsic to the variable (especially wind, but also precipitation and relative humidity, for example). Furthermore, by considering climatological values that, by definition, describe the atmospheric conditions of a place over a long period of time, we are reducing the variance of climatic elements, both in time and in space. For this reason, the resolution must be adapted both to the characteristics of the variable and to the purpose of the representation.

II.5.1.3.- Spatial coverage. -

The climate map covers the three geographical areas considered in the ARCAS project, corresponding to Spain, France, and Portugal. The availability of climatic data differs in each of the areas, In the Spanish area, the climatic information about temperature (T) and rain (P) has been obtained directly from the State Meteorological Agency (AEMET), which has developed different products in a grid format. These products have been generated from the observations of the climatological observatories network, which guarantee the comparison between stations, as well as the homogeneity standards that the data must satisfy. In addition to being properly treated and refined, the generation of the grids was done according to detailed and contrasted methods.

Another source of climate data, used in this case in the three geographical domains, is the ERA5-Land reanalysis generated in the European Union Earth Observation Program Copernicus, through its Climate Change Service (C3S), which focuses on providing information about past, current, and future weather.

Climate projections have been obtained from the EURO-CORDEX project. EURO-CORDEX is the European branch of the international CORDEX initiative, which is a program supported by the World Climate Research Program (WRCP) to organize an international coordinated framework that aims to improve regional climate projections in all terrestrial regions of the globe.

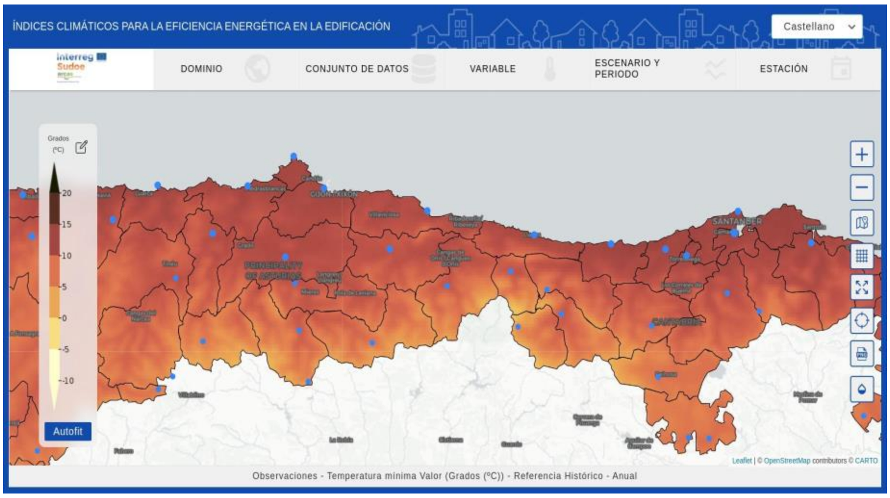
El objetivo es mejorar las proyecciones climáticas regionales en todas las regiones terrestres del globo. The CORDEX results serve as input for climate change adaptation and mitigation studies such as the IPCC Fifth and Sixth Assessment Reports.

EURO-CORDEX projections have a spatial resolution of 0.11º and greenhouse gas emission scenarios have been considered, RCP 4.5 and RCP 8.5.

Representative concentration paths (PCR) are greenhouse gas concentration paths (no emissions) adopted by the IPCC in the Assessment Report 5. The IPCC describes PCR 4.5 as an intermediate scenario that peaks around 2040 and is considered the most likely baseline scenario. (no climate policies) taking into account the exhaustibility of non-renewable fuels. On the other hand, in PCR 8.5 emissions continue to increase throughout the 21st century, and are considered highly unlikely.

II.5.1.4.- USER INTERFACE. -

The current version of the application is available at the following link: https://fecea-viewer.predictia.es.



Currently, the web viewer has a dynamic dropdown menu on the top, and the viewer itself at the bottom. In addition, these elements are interdependent so that the options shown are adapted depending on what the user chooses.

In the first dropdown, there is the geographic domain of the data where the user can select an area (Spain, France or Portugal).

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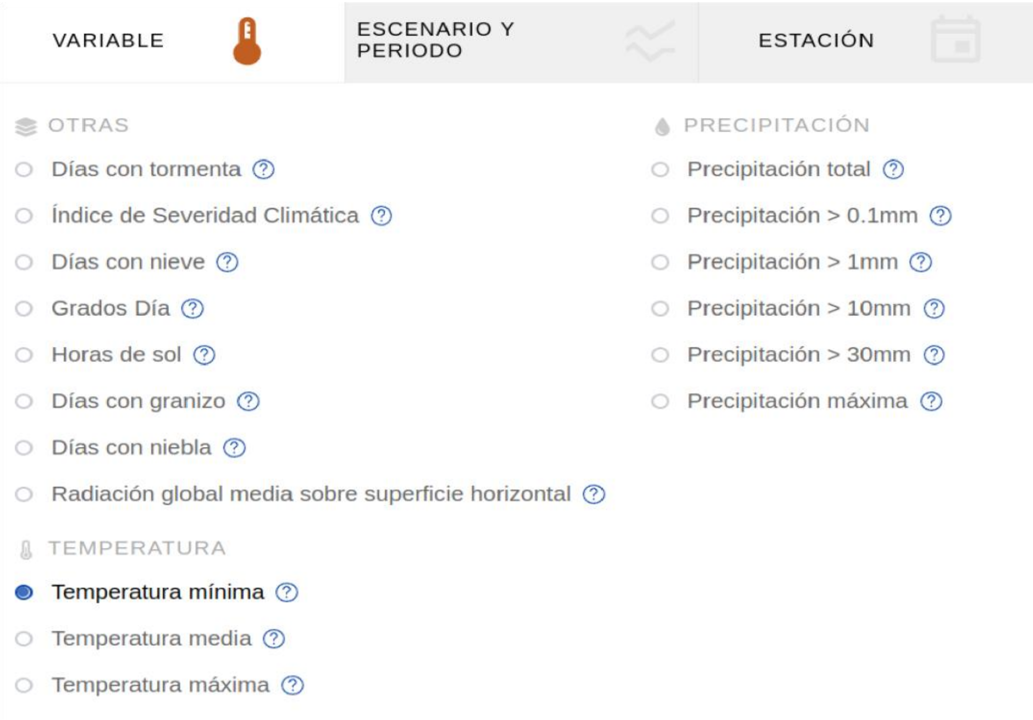
Following that, the type of data source can be selected. At the moment, there are three types of options: observations, reanalysis and climate projections :

The third dropdown lists the variables that are available for that type of source, grouped by type :



In the fourth dropdown includes options for predictions such as the future period (near, medium, or distant), the magnitude (specific value or anomaly) of the variable, or the type of scenario for the prediction :

The last dropdown shows a temporary disintegration filter in which different options are collected depending on their availability :

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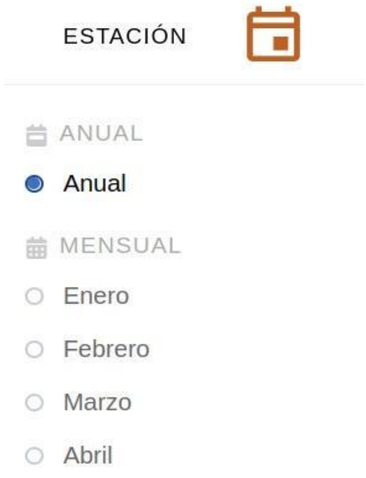
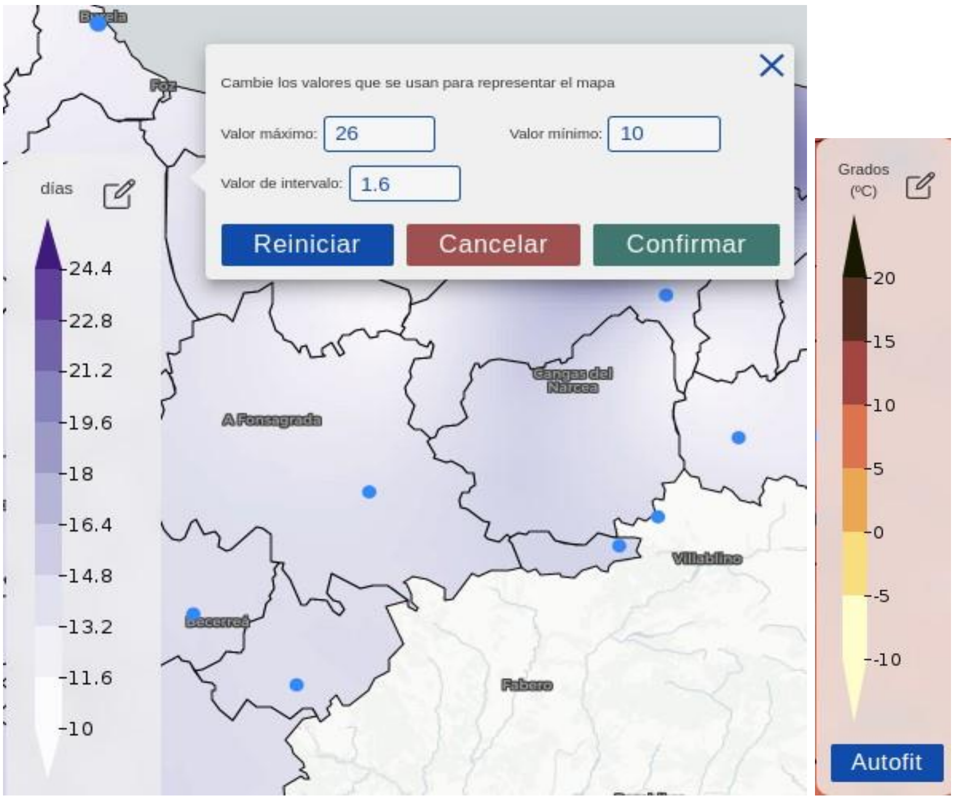


On the other hand, the viewer itself consists of a map, which shows the information chosen by the user combined with the available stations, some standard controls, and a dynamic legend. Currently, among these controls there is the possibility of zooming, choosing the type of map (such as orthophoto, street, dark, or light), making it full screen, obtaining information on a specific point on the map, downloading the map as an image and changing the opacity of the displayed layer. As for the legend, it provides an editor for the limit of magnitude established by default so that, if necessary for some variable, the colors of the layer can be displayed correctly (left). In addition, the option to auto-adjust the range to the maximum and minimum value displayed is included (right) :



SETTING UP OF THE LEGEND LIMITS (LEFT) AND AUTO-FIT BUTTON (RIGHT)

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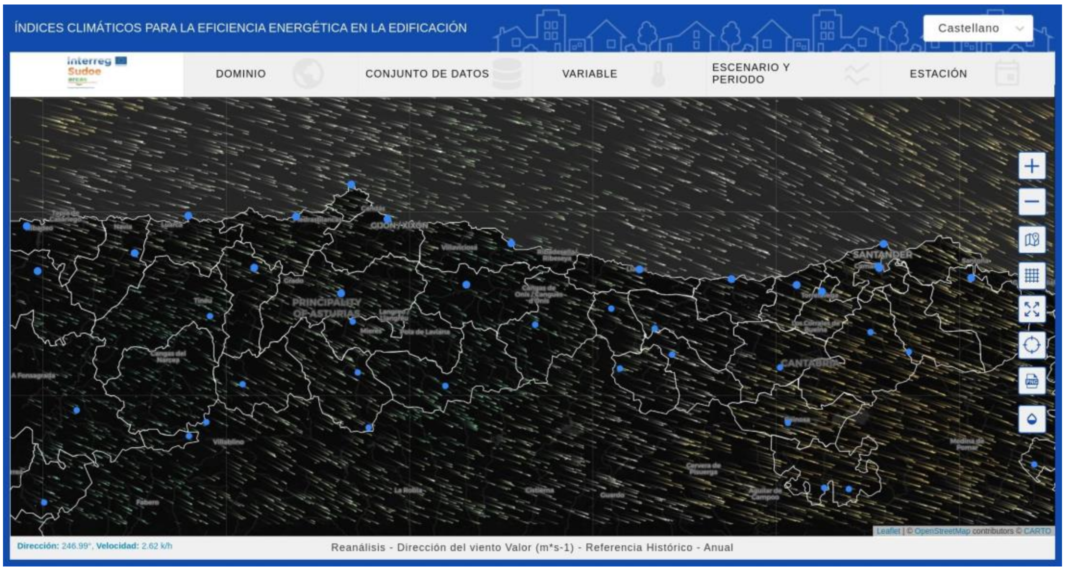
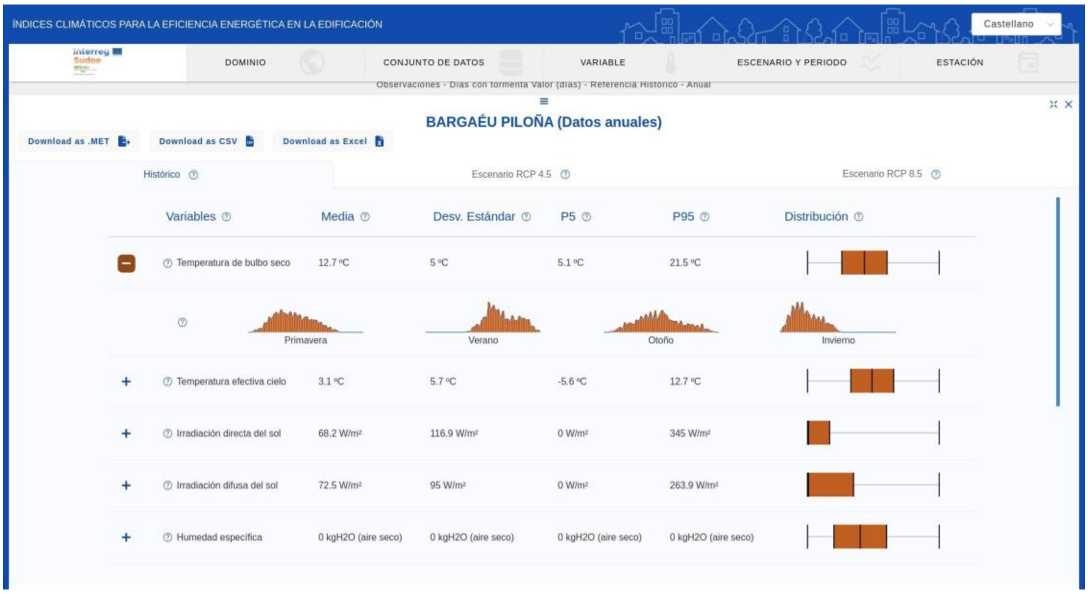
Each variable has been configured with a map of colors and ranges appropriate to its nature and magnitudes. All the variables are represented in the form of choropleths, except for the wind direction variable, which is represented as a vector.



REPRESENTATION OF THE WIND DIRECTION VARIABLE.

Apart from including weather in the layer of a map, the application offers detailed information on specific locations. To do this, the blue points represented on the map must be clicked. At that moment, a modal window appears to the user in which information is represented for different greenhouse gas emission scenarios (historical, RCP4.5 and RCP8.5). In each of the tabs, a table is included with the distribution of values of the different climatic variables. This distribution is characterized by some statistics, a box plot, and some seasonal histograms. In addition, the user is allowed to download this information or the files in .MET format generated by AEMET. This screen includes many help texts in order to make it self-explanatory. Equivalent functionalities are offered for France and Portugal.



DETAILED INFORMATION ON LOCATIONS

The application also includes these features:

- Translation into English and Spanish through a selector located on the right of the top menu
- Homepage with the geographical domains considered and information about the ARCAS project including partnership
- Specific base layers for each geographic domain (e.g., the National Air Orthophoto Plan-PNOA, for Spain).

II.5.2 – Best technologies available in Renewable Energies and Intelligent Energy Management Indicators

The objective of this section is to present a methodology to identify the best available technologies for the renovation strategy of social collective housing in the ARCAS project climate zone. It includes the definition of indicators and the production of guidelines for the selection and design of passive or active HVAC systems, focusing on those that use renewable energy.

The method consists, from the characteristics of the envelope and HVAC systems of an existing building, to develop a bioclimatic approach, to identify and implement passive heating, ventilation and cooling solutions adapted to the climates of the ARCAS-SUDOE area.

Two main steps can be identified:

1. Establish a catalogue of usual bioclimatic design solutions and the best passive heating, ventilation and cooling solutions adapted to the climates of the ARCAS-SUDOE zone
2. Propose indicators for energy efficiency, technical and economic aspects, health quality for active systems with a focus on those which use renewable energy.

This method can of course also be used in the design phase for a new construction project.

More details can be found in P3 report.

II.5.2.1 Initial state. Building envelope, HVAC systems and energy consumption

First of all, a description of the envelope characteristics, state of existing HVAC systems and observed energy consumption must be done.

An example of such a description sheet is given in Annex

II.5.2.2 Bioclimatic approach and related indicators

The bioclimatic approach allows during the design phase of a project to optimize the potential for the use of free inputs (solar in particular), in order to reduce heating needs, while ensuring good comfort conditions in all seasons, with particular attention to mid-season periods, which are conducive to the risk of overheating, and to a lesser extent the summer period.

Some basic principles are hereafter recalled, with a focus on common elements of the design of a building, by reviewing the elements/arrangements that seem most relevant in the context of a collective social housing operation, which is often financially constrained.

This approach applies at the level of the plot or neighbourhood as well as one or more buildings in the same operation.

At the building scale, we can distinguish different items:

- aspects related to the orientation and morphology of the building,
- quality of the envelope, which will allow to minimize the losses/ thermal loads by making the best use of the free resources (solar in particular) while guaranteeing a good comfort of use in all seasons.

- ***Orientation and morphology of a building***

Building orientation

Building orientation and layout are considered as one of the most effective strategies used in passive heating [3]. An appropriate orientation is a low cost option to optimize the solar heat gains on a façade and to prevent from strengthening of thermal losses from wind. It consequently decreases energy bills [4], [5]. In the Northern hemisphere, the best orientation for a rectangular building is to have its long side facing south in order to benefit from direct solar radiation during winter (North facing in the Southern hemisphere).

Of course, orientation of existing buildings cannot be changed, but this highlights the importance to well design the mass plan and the road networks for a new development project.

Morphological considerations and related indicators

Morphology of a building directly impacts its heat losses and gains.

- ***Shape coefficient***

The shape coefficient is generally defined by the ratio between the outdoor surface of a building envelope and its inner heated volume. In that case, it expresses in m^{-1}.

- ***Compactness***

The compactness is defined by the ratio between the deperditive surface of a building and its floor area. The more the compactness value, the more deperditive the building.

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- ***Envelope characteristics and performances***

Building envelopes need to have high performances, both in terms of insulation properties of opaque and glazed surfaces and for air tightness, in order to decrease the heat losses, to optimize the free gains and to ensure a sufficient air change rate for healthy indoor conditions.

- ***Glazed area***

  Glazed surfaces characteristics are of utmost importance because they allow to take advantage of the free solar gains to reduce the need for heating and artificial lighting and to prevent/reduce overheating in summer period.
  - ***Daylight factor*** (DF) describes the ratio of outside illuminance over inside illuminance, expressed in %. The higher the DF, the more natural light is available in the room. It is defined by DF = 100 * E_{in} / E_{ext}, where E_{in} represents the inside illuminance at a fixed point and E_{ext} the outside horizontal illuminance under an overcast or uniform sky. Rooms with a 2 % average DF are considered daylight. However, a room is only perceived as well daylight when DF is above 5 %.
  - ***Glazing ratio*** of a flat is defined by the ratio between the vertical glazed area and the living area (French definition). National rules can impose a minimum glazing ratio value for new buildings (1/6 in France as an example).
  - ***Thermal loss coefficient***, Uw, expressed in [$W.m^{-2}$. $Degree^{-1}$]. The lower Uw, the lower the heat losses.
  - ***Solar factor*** (g). Expresses the percentage of the total solar radiant heat energy entering a room through the glass, regardless of the wavelength and mode of transmission of the energy.
  - ***Light transmittance*** (LT). Expresses the ratio between the transmitted light flux and the incident light flux

  A compromise must be found between reducing heat losses (low Uw), the possibility of recovering solar gains (g) and access to natural light (LT) while preserving summer comfort. This is achieved by surface treatment of one or more sides of the double or triple glazing and the use of rare gases (Argon, Krypton).

  Currently, usual encountered values for double glazing are respectively Uw = 1.1 $W.m^{-2}$. $Degree^{-1}$; g = 0.5 and TL =0.6 (see [1] as an example).

  One should have in mind that for moderate latitudes, modern glazed surfaces always present a positive energy balance during the winter period, whatever the orientation. In harsh climates, the use of triple glazing can further reduce heat losses.

- ***Airtightness of the envelope***

  Particular attention should be paid to the air permeability of the envelope in order to control as well as possible the air change of dwellings to ensure good indoor air quality and to limit the thermal losses related to infiltrations. Energy retrofit projects provide opportunities to improve the air permeability of old buildings, which is often very important in particular because of the leaky frames, and to implement an efficient ventilation system with controlled air intakes.

  Airtightness must be consistent with the thermal performances of opaque and glazed walls. The more efficient they are, the less air permeability must be. As an example, the n_{50} coefficient required for Passivhauss label must be less than 0.6 h^{-1} for new or renovated buildings.

- ***Heat Loss coefficient***
  The Heat Loss Coefficient (HLC) measures the total thermal losses of the building through the envelope (including thermal bridges and total air change) per unit of indoor and outdoor temperature difference. It expresses in W/degree.

- ***Reducing the thermal discomfort***

Solar gains can cause overheating and discomfort situation in mid and summer periods due to high and uncontrolled solar gains.

- ***Shading techniques***
  The main purpose of shading systems is to reduce heat gains and indoor temperature increase due to surrounding factors caused mainly by direct, reflected or diffuse solar radiation.

- ***Vegetated facades***
  Vegetating the facades with deciduous plants allows to pass the light in winter and to more or less obscure the facade in summer. They also contributes to reduce the urban heat island locally through evapotranspiration phenomena and to purify the outside air.

- ***Roof treatment***
  - ***Cool roofs***. Metal and flat roofs (mainly) may be subject to selective coating treatments. These radiation-based passive techniques allow a significant proportion of solar radiation to be re-emitted compared to conventional coatings and thus reduce the thermal loads on the roof.

  - ***Green roofs***. Vegetating the roofs to reduce solar gains can be treated in different ways:

    - with a consequent thickness of substrate, which makes it possible to plant shrubs and plants,

    - with a low substrate thickness, vegetated with plants that require little water and maintenance such as sedans

    In both cases, the insulation and inertia of the roof are increased and these devices contribute to reduce the urban heat island. They also regulate rainwater supplies in drainage systems

- ***Energy needs and Bioclimatic factor***

- ***Energy needs***
  For heating or cooling. Heat to be delivered to or extracted from a thermally conditioned space to maintain the intended space temperature conditions during a given period of time. Different terms can be identified:

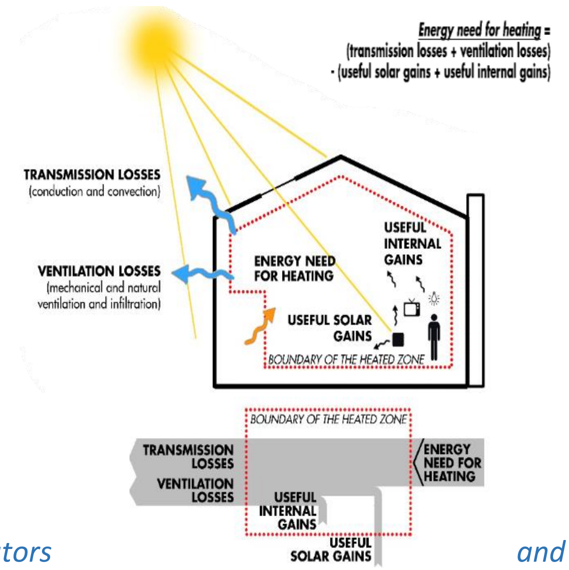

Figure 1: indicators and assessment methods for cost effective nearly Zero Energy Buildings (nZEB) and Positive Energy Buildings [2]

- the ***raw need*** of a building which corresponds to the energy need for balancing the heat losses (transmission and ventilation losses),
- the ***useful free gains*** (solar, internal),
- the ***energy need*** or ***net energy need***, which results from the raw need minus the useful free gains. In a cooling situation, the energy need will be the sum of the raw need plus the free gains.
- The ***coverage rate*** is the part of the raw energy need covered by the useful free gains:

$$\tau_{cov} = \frac{Raw\ needs - net\ energy\ needs}{Raw\ needs}$$

- ***Bioclimatic factor***

A bioclimatic factor can be defined to characterize the energy requirement of the building linked to the design (passive heating, passive cooling and access to daylight), without considering the HVAC system and other technical facilities.
As an example, the French environmental regulation (RE2020, [3]) defines for all new buildings project the bioclimatic factor Bbio as:

Bbio = 2 x Heating need + 2 x Cooling need + 5 x Artificial lighting need

Bbio is obtained from a yearly dynamic thermal simulation from hourly heating, cooling and lighting needs of the building, considering conventional scenario for meteorological conditions, internal gains, occupation, and DHW needs.

While the needs are expressed in *kWh/m²*, Bbio expresses in *points* and must not exceed a maximum value ($Bbio_{max}$), defined according to the use and type of building, its surface area, its location and the altitude at which it is located.

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- ***Discomfort indicators***

Different comfort analysis are available with more or less complex definitions. An example suitable for buildings without air conditioning systems for defining different classes of indoor comfort is given from EN 15251 standard, based on the adaptive comfort approach [4].

Derived indicators can be obtained from measurement or simulations:

- ***Overheating hours*** in the summer period. It is the number of hours during a period for which the indoor (ideally operative) temperature is higher than a given temperature level,
- ***Percentage of discomfort***. It is the ratio between the number of overheating hours and the total number of hours for a given period.
- ***Overheating degree.hours (ODH)***, defined as :

$$ODH = \sum_{month} (T_{op,i} - 27) \times N_i$$

where N_i is the number of hours for which the operative temperature $T_{op,i} > 27$ °C is observed, following the different comfort classes proposed by Olesen et al. [5].

Similar definitions can be obtained for heating period discomfort with indoor temperature values lower than a temperature level.

- ***Near passive systems to prevent overheating***

Near-passive systems are those that use little or no electrical or mechanical energy (unlike active systems such Heat Pumps). These systems are an integral part of the bioclimatic approach, complementing the envelope design.

- ***Free cooling and night time over-ventilation***

  Free cooling is encountered in tertiary buildings equipped with air handling units and consists in switching to full fresh air ventilation mode when the outside air is colder than the inside air, without changing the flow rate.

  Over-ventilation techniques consist in increasing the supply airflow rate by a significant amount (of the order of 3 Air Change Rate – ACH- , instead of typically 0.5 ACH for basic ventilation).

  They are mainly used during night-time when the outside air allows to release the heat absorbed by the building thermal mass and to cool it, thus delaying the need for active cooling in daytime.

  For residential buildings, over-ventilation can be achieved by natural ventilation or mechanical systems, through either individual or collective installations
- ***Geothermal air preconditioning***

  Pre-heating or cooling the supply air entering a building can be achieved by the use of so-called earth pipes, which are pipes buried at shallow depth (typically between 1 and 2 m). The air can then be blown directly in the rooms (single flow ventilation system) or coupled to a heat recovery exchanger (dual flow ventilation system). These systems are more efficient in the climates with strong temperature differences between day and night, or contrasting climates

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- ***Proposal of some key indicators***

From this review, some indicators are proposed for qualifying the bioclimatic performance of a building (*Table 1*).

Table 1: summary of proposed bioclimatic indicators

Type of indicator		
Building indicator	***Envelope indicator***	***Performance indicator***
Main orientation	Ratio of glazed surface	Bbio coefficient
Compactness, C	Daylight Factor, DF	Useful free gains coverage rate
	Airtightness coefficient, n_{50}	Overheating degree.hours, ODH
	Heat Loss coefficient, HLC	

II.5.2.3 Renewable energy production and indicators

A key issue in a building renovation project is, in addition to reducing needs, the possibility of having a renewable energy source production.

We focus on the evaluation of the potential integration of renewable energy and advice on energy system selection, with complement from the renewable energy self consumption and self sufficiency ratios defined in the previous section.

The production technologies evaluated in the ARCAS project will be mainly related to on-site technologies (*Figure 2*), such as PV panels producing electricity or solar panels producing heat. The case of local PV production will be especially detailed here as there is a strong development in this field and it could bring some challenges in terms of grid interaction.

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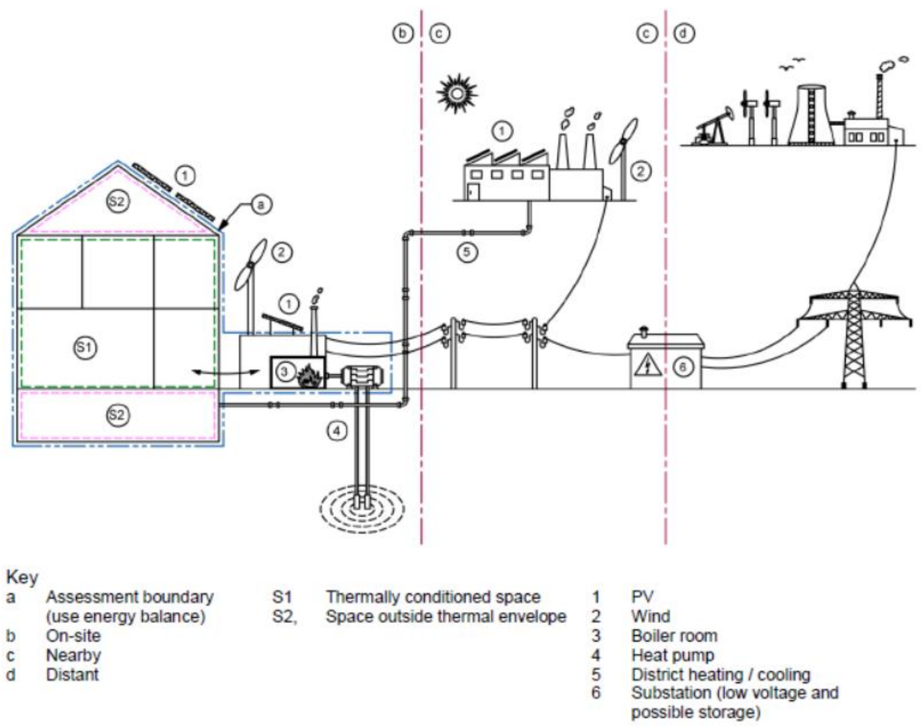

Figure 2: Building assessment boundary and energy balance locations [2]

- ***Load-matching metrics***

Among the load matching metrics, three indicators are often used in the literature to quantify and compare the local production to the consumption (*Figure 3*). For the sake of clarity, the definitions are illustrated with the case shown in the following Figure, considering PV production.

- The self-consumption corresponds to the self-consumed part relative to the total production:

$$self - consumption\ ratio = \frac{C}{B + C}$$

- The self-sufficiency corresponds to the self-consumed part relative to the total load:

$$self - sufficiency\ ratio = \frac{C}{A + C}$$

- The self-production corresponds to the total production relative to the total load. Thus, it does not give an indication on the load-matching, only in the total quantities.

$$self - production\ ratio = \frac{B+C}{A + C}$$

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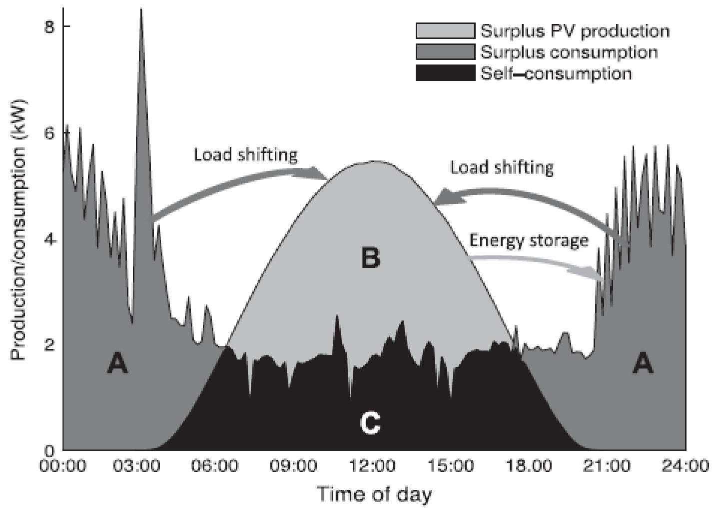

Figure 3: Daily profile of energy consumption of PV production (from Luthander et al.)

Using only one of these indicators could lead to a biased interpretation of the technology under study. Luthander et al. [XX] proposed the "energy matching chart", which is a graphical visualization of self-consumption and self-sufficiency in buildings with local energy generation (*Figure 4).*

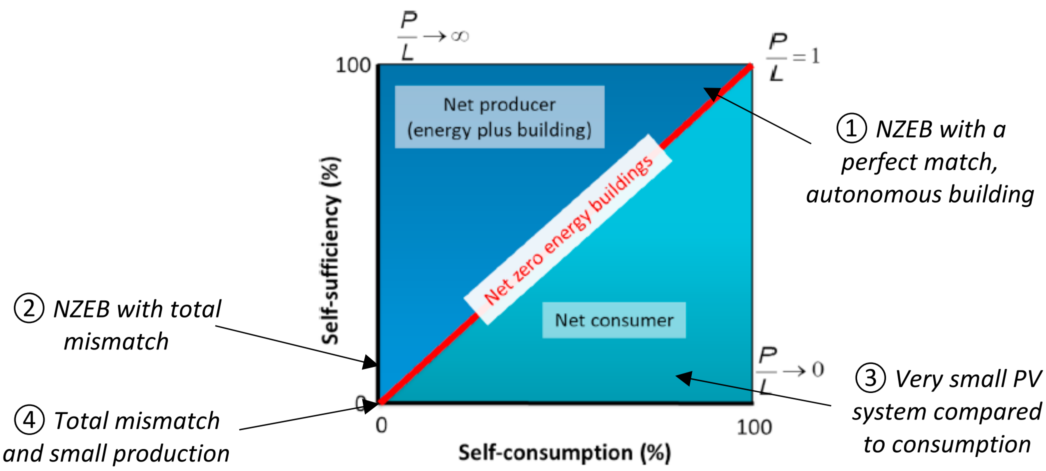

Figure 45: The principles of the "Energy matching chart", proposing a visualisation of the matching in time and size (from Luthander et al.)

The Grid Support Coefficient has been introduced by Klein et al. [YY]. It quantifies the coincidence of a load profile and the relative availability of electricity in the energy system. The GSC calculation by equation (1) requires the hourly energy consumption of the building W_{el}^{i} and the value of the grid-based reference quantity G^{i}:

$$GSC_{abs}(G) = \frac{\sum_{i=1}^{n} W_{el}^{i} \cdot G^{i}}{W_{el} \cdot \bar{G}} \; [-] \qquad (1)$$

where:

$$W_{el} = \sum_{i=1}^{n} W_{el}^{i} \; [kWh]$$

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$$\bar{G} = \frac{1}{n}\sum_{i=1}^{n} G^{i}$$

The grid-based reference quantity should have an increasing trend in case of stress on the grid and a decreasing trend otherwise. The lower the grid support coefficient, the better for the energy grid.

An example of the calculation is given in ***¡Error! No se encuentra el origen de la referencia.****5* using the spot price (market) as an indicator of the grid stress. The grid-supportive building (green curve) is using energy during the lowest price period (GSC_{abs} = 0.8). The grid-adverse building (red curve) is using energy during the highest price period (GSC_{abs} = 1.14).

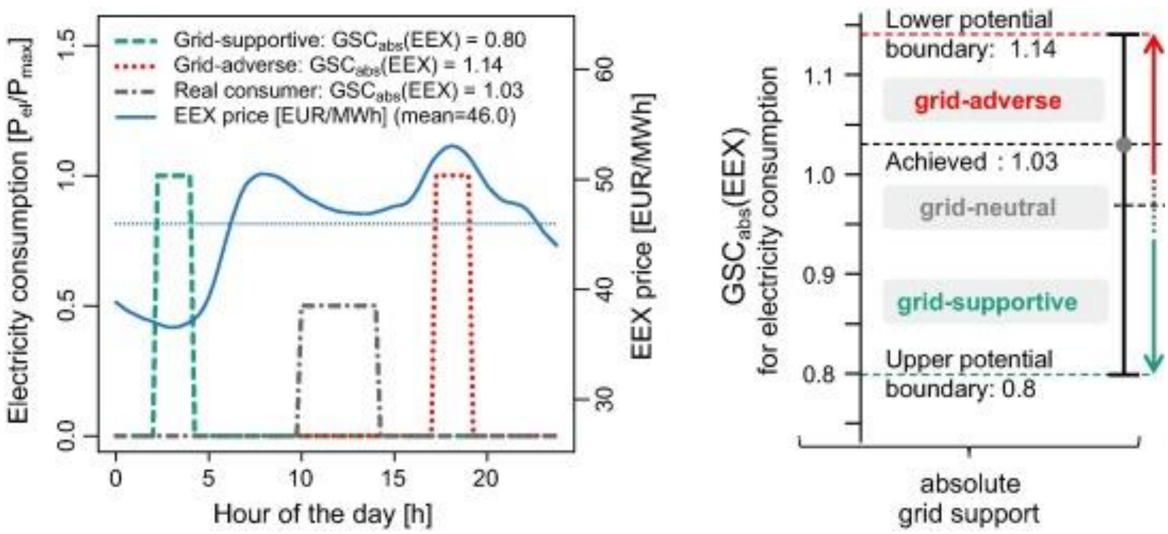

Figure 5: Example of calculation of the Grid Support Coefficients using the spot price as an example of the grid-based reference quantity (from Klein et al.)

The main advantage of this coefficient is that different grid-based reference quantities can be tested depending on the objective of the building (cost reduction, renewable integration, grid stability, etc). An example is given in ***¡Error! No se encuentra el origen de la referencia.,*** where the control of a heat pump is set according to different signals: day-ahead spot-price (EEX), residual load (RES), (non-renewable) cumulative energy consumption (CEC), fraction of wind and PV in the electricity mix (WPV), etc.

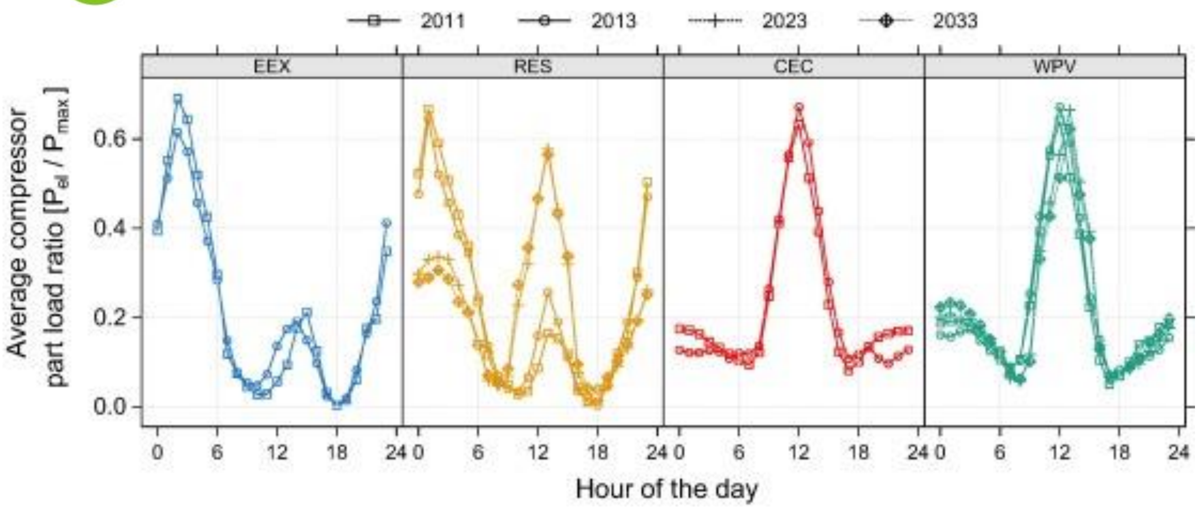

Figure 6: Different optimal consumption profiles depending on the grid-based reference quantity

II.5.2.4 Best HVAC technologies choice guide

- ***General considerations on HVAC systems***

This part is devoted to a multi-criteria methodology aiming to help the project owners or engineering offices during the design of a rehabilitation or new construction project, for the choice of the active HVAC systems.

The identification of the best strategy for the HVAC system replacement is generally tricky for many reasons. The first is the large variety of system types and technologies, and an even greater variety of offers on the market. Furthermore, several functionalities can be performed by a unique system. Another reason is that the selection of the system depends on many technical criteria, only known by designers. Most of these criteria are related to constraints from the existing building. Others depend on exogenous factors, such as the target for the energy performance or thermal comfort and can be clearly expressed only by experts.

Finally, yet importantly, the cost of a solution is an important criteria.

Thus, the possible choices for the replacement of HVAC systems depend on both intrinsic and extrinsic parameters. Intrinsic parameters are those related to the existing building and its HVAC systems. Extrinsic parameters are those related to the building environment and the renovation operation itself. Identifying and formalizing these factors enables to clarify the design methodology for the HVAC systems replacement. The final objective is to supply to the building owner relevant information regarding the best-suited HVAC systems, considering the building integration easiness, the renovation operation objectives, the global energy efficiency, and the cost aspects.

This part is organized as follow:

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- First, we consider the particular case of ventilation systems and the best system choice as it appears from a parametric study done on a typical flat
- Second, general discussion presents the possible energy sources and the different applications they allow, according to the type of installation (individual or collective) and the sources used (renewable or not)
- Then, a non-exhaustive list of possible influencing factors is proposed, taking into account the existing building and systems as well as extrinsic parameters
- The following section proposes a set of HVAC systems for the replacement of the old ones. This document does not list exhaustively all the possible HVAC systems, but focuses on the most frequent and relevant ones, using or not renewable energy
- A costing methodology is then introduced for each system, to be adapted to national or local market
- Finally, the last section exposes a global methodology for the ranking (and therefore for the choice) of the HVAC systems by the way of a Multi-criteria Decision Helping Tool

- ***Focus on ventilation systems***

Among HVAC systems, a focus must be made on ventilation systems as they are of primary importance to ensure healthy indoor conditions.

A review of the evolutions of the national regulations in France, Portugal and Spain, shows similar trends in terms of principle from separated rooms to whole general and permanent ventilation, and evolution from natural to mechanical/hybrid ventilation and pressure/humidity-controlled systems [ref P3].

A case study based on the French regulation [réf P3] allowed to compare different ventilation systems in terms of indoor air quality regarding typical indoor pollutants production, and serves to draw general figures for the ARCAS buildings renovation strategy of ventilation systems for combining indoor air quality and energy conservation:

- In the case where the kitchen is separated from the living-room, mechanical whole-building ventilation systems are to be preferred.
- In the case of merged kitchen and living room, natural ducted and assisted ventilation systems offer an air quality relatively close to what could be achieved with mechanical systems, but lead to a higher power consumption than controlled mechanical ventilation.
- Humidity-controlled mechanical system is the best option for energy savings and a very good one for indoor air quality.

The merged kitchen and living-room configuration is always the most suitable in terms of pollutant concentrations, regardless the ventilation system. This is particularly noticeable for $PM_{2.5}$ and NO_2 with natural ventilation systems with separate rooms. This comes from the fact that cooking emission is then diluted in higher volume (living-room + kitchen). Nevertheless, we must notice that this analysis does not account for the presence of a hood in the kitchen, as it is not strictly speaking a ventilation system. The systematic use of such an additional system is however a key element to reduce exposure from cooking pollutants.

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- ***Other HVAC systems***

For other active heating, cooling and hot water production systems, the following section proposes a set (necessarily not exhaustive,) of HVAC systems for the replacement of the old ones, but first we present the possible energy sources and the different applications they allow, according to the type of installation (individual or collective) and the sources used (renewable or not).

The presentation follows the following logic:

Energy source or energy vector
Renewable or non-renewable character
Uses: systems description and individual/collective character

Fossils fuels
Non-renewable
Heating, DHW: individual or collective boilers
Cooling: absorption (individual or collective) and desiccant systems (collective)

Electricity
Non-renewable (fossil fuels and nuclear power plants)
Renewable (photovoltaic, biomass, solar, hydraulic, high temperature groundwater or wind power plants)
Heating, DHW: individual or collective systems
Cooling: compression heat pump systems (individual or collective)

Biomass
Renewable
Heating, DHW: individual or collective boilers
Cooling: absorption and desiccant systems (collective)

Thermal solar
Renewable
Heating, DHW: individual or collective systems
Cooling: absorption and desiccant systems (collective)

Ground
Renewable
Heating, DHW: water direct geothermal heating, groundwater or ground source compression heat pump systems (individual or collective)
Cooling: groundwater or ground source compression heat pump systems (individual or collective)
Pre-heating and pre-cooling: earth pipes (individual or collective)

Water
As already mentioned, groundwater can be used directly for preheating or heating purposes, and for electricity generation if available at a sufficiently high temperature level. Water also serves as a thermal source for thermodynamic systems such as heat pumps.

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Lastly it can be used for direct or indirect adiabatic cooling process in air handling units, which nevertheless are in the domain of tertiary buildings rather than residential buildings.

- ***Key factors for the HVAC system selection and pre-sizing***

Let us now list possible influencing factors, taking into account the existing building and systems as well as extrinsic parameters The intrinsic and extrinsic factors can be organized into three different groups: the constraints, the opportunities and the objectives, summarized in *Table 2.* The constraints enable to remove some of the possible systems: the field of possibilities is therefore reduced, and the problem of HVAC systems selection simplified. The opportunities and the objectives guide the choices towards potentially suitable systems.

Table 2: Extrinsic factors influencing the renovation actions selection

1.	**Constraints**
1.a. Constraints linked to the renovation operation specificities	
	Budget
	Works on an occupied site
	Limited work period
1.b. Constraints linked to the building envelope specifications	
	Urban rules: no modification allowed of the roof / façade appearance
	No available roof / façade surface
	No available land near the building
	Shadings or masks from neighbouring buildings, relief or vegetation
	Size of the housings
	Limited possibilities of drilling the outdoor walls
1.c. Constraints linked to the building HVAC systems specifications	
	No available passage for ducts/pipes
	No available / not enough space in common technical rooms
	No available / not enough space in flat technical rooms
2.	**Opportunities**
2.a. Opportunities linked to the renovation operation specificities	
	High energy consumption for heating/cooling / DHW
	High energy needs for DHW
	Poor winter/summer thermal comfort
	Poor indoor air quality for some rooms/flats/common spaces
2.b. Opportunities linked to the building envelope specifications	
	Urban rules: modifications allowed of the roof/façade appearance
	No shading/masks from neighbouring buildings, relief or vegetation
	Size of the housings
	Possibilities of drilling the outdoor walls
2.c. Opportunities linked to the building HVAC systems specifications	
	Cf. following tables
3.	**Objectives**
	Improve the aesthetical aspect of the building
	Reduce the building energy needs
	Reduce the building energy consumption
	Reach certification or label requirements
	Reduce the environmental footprint
	Improve the thermal comfort of the occupants
	Improve the HVAC systems-occupant interactions
	Carry out the maintenance operation
	Reduce the rental costs
	Make the maintenance operation easier
	Design a reproducible renovation strategy
	Design a custom-made renovation strategy

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Table 3 is an example for the description of existing building HVAC systems for heating and DHW production and emission, and a methodology to describe their state. The main objective is here to detect potential opportunities for renovation. Concerning the state of the system, a simple assessment rating is proposed to identify the possible improvements or replacements.

Table 4 then proposes a list of potential systems for renovation. As previously, it is ordered according to the type of service supplied. Indeed, the diagnosis carried out previously highlights the systems and thus the services to be replaced. A combination of services can be selected, for instance, heating only and DHW only and ventilation only. For each service, the generation can be collective or individual. The latter can be combined with several possible emissions and eventually supplemental.

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Table 39: Description and state of existing systems for heating & DHW

Type of service		Type of generator	Type of emission	Type of supplemental	Type of storage	Generator state	Emission state	Distribution network state	Storage state
Heating and DHW	Collective	1. Oil-fired boiler 2. Gas boiler 3. Wood boiler 4. Urban heating network	1. HT water radiator 2. LT water radiator 3. Hydraulic floor heating 4. Radiant ceiling	1. None 2. Bathroom heater 3. Electric radiator 4. Electric radiator and bathroom heater	1. Stored 2. Stored and looped 3. Instantaneous	1. New or less than 5 years 2. Good 3. Good but no regulation 4. Poor	1. New or less than 5 years 2. Good 3. Good but no regulation 4. Poor	1. New or less than 5 years 2. Good and lagged 3. Good but poorly lagged 4. Poor	1. New or less than 5 years 2. Good, adequate volume and lagged 3. Good, insufficient volume and lagged 4. Good, insufficient volume and poorly lagged 5. Good, adequate volume and poorly lagged 6. Poor

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Table 4: Description of possible renovation systems for heating & DHW

<table>
<tr><th colspan="2">Type of service</th><th>Type of generator</th><th>Type of supplemental</th><th>Type of emission</th><th>Type of storage</th></tr>
<tr><td rowspan="3">Heating and DHW</td><td rowspan="2">Collective</td><td>1. Gas boiler
2. Wood boiler
3. Urban heating network</td><td>1. None
2. Bathroom heater
3. Electric radiator
4. Electric radiator and bathroom heater
5. Individual HP A/A</td><td rowspan="3">1. LT water radiator
2. Hydraulic floor heating
3. Radiant ceiling</td><td rowspan="2">1. Stored
2. Stored and looped
3. Instantaneous</td></tr>
<tr><td>1. HP Air/Water
2. HP Water/Water
3. Solar water heater
4. Hybrid PVT</td><td>1. None
2. Gas boiler
3. Bathroom heater
4. Electric radiator
5. Electric radiator and bathroom heater
6. Individual HP A/A</td></tr>
<tr><td>Individual</td><td>1. Gas boiler
2. HP Air/Water</td><td>1. None
2. Bathroom heater
3. Electric radiator
4. Electric radiator and bathroom heater</td><td>1. Stored
2. Micro-Stored
3. Instantaneous</td></tr>
</table>

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Table 5: Proposal for cost estimation of heating & DHW systems

		Type of generator	Unit	Unit price min (€)	Unit price max [€]	Details
Heating and DHW	Collective generation	1. Gas boiler	kW	90xP	350xP	power
		2. Wood boiler	?	?	?	?
		3. Urban heating network	m	400xL	450xL	connection length
			kW	75xP	100xP	power
		4. HP A/W	kW	350xP	375xP	power
		5. HP W/W	kW	400xP	450xP	power
		6. Solar water heater	m^2	850xS	1000xS	collector area
			kWh/an	800xE	950xE	annual solar energy production
		7. Hybrid PVT	?	?	?	?
	Individual generation	1. Gas boiler	kW	90xP	350xP	power
		2. HP Air/Water	kW	350xP	375xP	power
	Supplemental	1. Bathroom heater	kW	450xP	1500xP	material
			-	100	250	installation
		2. Electric radiator	kW	200xP	350xP	material
			kW	100xP	350xP	installation
		3. Individual HP A/A	m^2	52,436xS + 295,05	93,657xS - 1097,7	housing area
		4. Gas boiler	kW	90xP	350xP	power
	Emission	1. LT water radiator	-	200	350	installation
			kW	100xP	200xP	material
		2. Hydraulic floor heating	m2	44xS	55xS	heated area
		3. Radiant ceiling	?	?	?	
	Storage	1. Tank	?	?	?	?

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Then, a method is proposed for estimating the cost of systems and their implementation, excluding taxes. The objective is not to provide an accurate quotation, but to obtain a rough estimation of the renovation strategy cost as one of the possible assessment indicators (energy performance, comfort, works easiness, etc.) and to give relevant information to compare several systems.

The price is of course the results of endogenous technical factors (size, performance, project specificities, etc.), and of exogenous factors (location, conjuncture, manufacturer, installer, etc.).

The exogenous factors are by definition hardly predictable. Low and high values are proposed as a first approach, but it could also be interesting to yield the median value and the variance that give more details about the cost breakdown.

Concerning the endogenous factors, a few of them enables to explain one system price. Typically, the price of a gas boiler is strongly dependent on its power. All the other factors can be treated as statistical variance around this estimation.

Most of the time, one factor has been retained, sometimes two. In the case of two factors, the cost has to be summed to get an estimation of the system. For example, the cost of the replacement of one low-temperature heater is given by the sum of one term depending on its power (representing the material) and one term proportional to the number of heater. The minimum price for a 1.5kW low-temperature heater is then 100x1.5+200=350 € and the maximum 200x1.5+350=650 €. The total cost of the renovation is the sum of the different new systems. The parametric nature of these evaluations allows adapting them to each local situation, and missing information could be filled as data become available.

Table 5 presents an example of this approach for heating and DHW systems, based on French observed values, but must of course adapted to each situation.

- ***Multi-criteria decision tool***

The multi-criteria analysis is a field of study whose aim is to compare strategies in order to help in choosing, sorting and classifying the results (in accordance with the decision-making problem to be addressed).

Among all existing methods (such as Electre, MacBeth and Promethee), TOPSIS (Technique for Order of Preference by Similarity to Ideal Solution) method is intuitive and easy to implement. The calculation is fast. Moreover, it is suitable for comparing a very large number of alternatives. It easily supports the addition and deletion of alternatives in the decision matrix. It allows the classification of the strategies according to a restricted set of indicators. The user can rank these indicators according to his preferences (from the most important for planning to the least important). The TOPSIS algorithm then returns a ranking of the strategies according to these criteria.

This ranking is achieved by following these steps:

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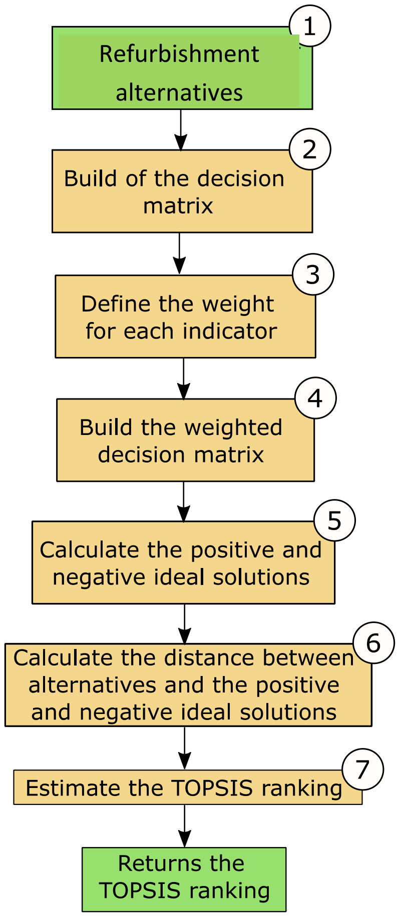

Figure 7: Flowchart of the TOPSIS method

- ***Illustration of the method***

A simple illustration is given in the following: let us consider a renovation project for the heating/cooling and DHW production systems of a ten-flats building in France. The decision maker considers 5 possible alternatives (**step 1**):

- The first alternative is a full collective two-service solution based on a gas boiler.
- The second is similar but the low temperature radiators are replaced by a hydraulic heating floor.
- The third is equivalent to the second one, but a cooling production is added and supplied by an independent air/air heat-pump.
- The fourth considers an individual two-service air/air heat-pump for heating and cooling in addition to a collective single service solar water system for domestic hot water (DHW).
- The fifth is a fully individual system, which combines electric radiant panels and thermodynamic DHW production.

Five criteria are considered for the decision:

- The first criterion is the final energy consumption;
- The second is the investment cost by dwelling, accounting for both material and installation;

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- The third is the evaluation of the ease of use of the systems, based on a 5 levels grade (1 for the easiest to use, 5 for the worst).
- The fourth is the thermal comfort associated to each system, based on a 5 levels grade (1 for the strategies offering the best comfort);
- The last criterion is the CO2 emission, including only the annual emissions relative to the energy consumption.

The following table summarizes the situation as the decision matrix (**step 2**), with typical associated French values for quantitative criteria.

Table 6: Decision matrix - example for the replacement of the heating/cooling and DHW systems

	Alternatives				*Criteria*				
	Type of service		**Type of generator**	**Type of emission**	**Final energy consumption ($kWh.m^{-2}.yr^{-1}$)**	**Investment cost (k€/dw)**	**Ease of use [-]**	**Thermal Comfort [-]**	**CO2 emission ($kgCO2.\ m^{-2}.yr^{-1}$)**
1	*Heating and DHW*	*Collective*	*Gas boiler*	*LT water radiator*	85	10	2	4	17
2	*Heating and DHW*	*Collective*	*Gas boiler*	*Hydraulic heating floor*	80	15	3	3	16
3	*Heating and DHW*	*Collective*	*Gas boiler*	*Hydraulic heating floor*	105	18	4	1	23
	Cooling only	*Individual*	*HP A/A*	*Fan*					
4	*Heating and cooling*	*Individual*	*HP A/A*	*Fan*	50	20	3	2	16
	DHW only	*Collective*	*Solar water heater*	*Stored*					
5	*Heating only*	*Individual*	*Radiant panels*	*n.a.*	45	10	1	2	15
	DHW only	*Individual*	*Thermodynamics water heater*	*Stored*					

Next, the decision-maker must set priorities by scoring each criterion (1 for the most important to 5 for the less important), as for an example this first set of priorities:

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Table 7: Example of priorities of the different alternatives.

	Final energy consumption ($kWh.m^{-2}.yr^{-1}$)	Investment cost (k€/dw)	Ease of use [-]	Thermal Comfort [-]	CO2 emission ($kgCO2.\ m^{-2}.yr^{-1}$)
Priority	**4**	**1**	**2**	**3**	**5**

TOPSIS method requires to affect different normalized weights (meaning that the sum of the weights is equal to 1) to each of the criteria, accounting for the priorities (**step 3**). Of the various possible methods to define theses weights, the present example uses the Rank Order Centroid (ROC), which is widely used, robust and easy to implement.

This results in a weighted MxN matrix (M=5 being the number of alternatives and N=5 the number of criteria) whose elements express as (**step 4**):

$$t_{ij} = \frac{x_{ij}}{\left[\sum_{i=1}^{M} x_{ij}^2\right]^{1/2}} . W_j$$

and $\sum_{k=1}^{N} W_k = 1$.

Elements x_{ij} are the values of the criterion C_j for the alternative *i* (cf. *Table* 6).

Best and Worst ideal solutions can then be obtained.

In the case under study, the criteria are better when their values are low. Therefore, the best ideal solution ($\boldsymbol{t_j^+}$) is obtained when the criterion value is minimum and the worst solution ($\boldsymbol{t_j^-}$) when the criterion value is maximum (step 5):

$$\begin{cases} t_j^+ = \min\limits_{i=1,M} t_{ij} \\ t_j^- = \max\limits_{i=1,M} t_{ij} \end{cases}$$

Furthermore, Euclidian distances (d_i^+ and d_i^-) are calculated between each alternative and respectively best and worst ideal solutions considering the *N* criteria (**step 6**).

$$\begin{cases} d_i^+ = \left[\sum_{j=1}^{N} \left(t_{ij} - t_j^+\right)^2\right]^{1/2} \\ d_i^- = \left[\sum_{j=1}^{N} \left(t_{ij} - t_j^-\right)^2\right]^{1/2} \end{cases}$$

Two rankings based on these distances, one according to the best and the other according to the worst solutions, are finally yielded and result in the TOPSIS ranking (**step 7**).

Coming back to the present illustration (5 alternatives and 5 criteria), the following rankings are obtained and designates alternative 5 as the best choice, followed by alternative 1 (*Table* 8).

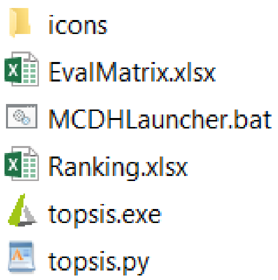
Table 8: Decision matrix – TOPSIS ranking

	Alternatives				*TOPSIS ranking*	
	Type of service		**Type of generator**	**Type of emission**	**Rank to best solution**	**Rank to worst solution**
1	*Heating and DHW*	*Collective*	*Gas boiler*	*LT water radiator*	**2**	**4**
2	*Heating and DHW*	*Collective*	*Gas boiler*	*Hydraulic heating floor*	**3**	**3**
3	*Heating and DHW*	*Collective*	*Gas boiler*	*Hydraulic heating floor*	**4**	**2**
	Cooling only	*Individual*	*HP A/A*	*Fan*		
4	*Heating and cooling*	*Individual*	*HP A/A*	*Fan*	**5**	**1**
	DHW only	*Collective*	*Solar water heater*	*Stored*		
5	*Heating only*	*Individual*	*Radiant panels*	*n.a.*	**1**	**5**
	DHW only	*Individual*	*Thermodynamics water heater*	*Stored*		

- ***MCDH toolkit***

A Multi Criteria Decision Helping tool is developed with the TOPSIS procedure described above, and allow decision makers to define their own set of values.

The MCDH.rar archive contains the following files:



The EvalMatrix.xlsx file allows to fit its own problem (the data of the previous test case are reported in the file for convenience).

The number of criteria and alternatives to sort has to be supplied. Then, the assessment matrix has to be fulfilled with correct values.

The priority of each criterion has to be given – 1 for the most important criteria - on line D from column 3.

The minimization direction must be set on line E. “1” indicates than the criteria must be minimized, and “0” if it must be maximized, to obtain the best value.

Double-clicking on MCDHLauncher.bat run the topsis.exe program and yields, in the same folder, a Ranking.xlsx file containing the best and worst rankings for the alternatives.

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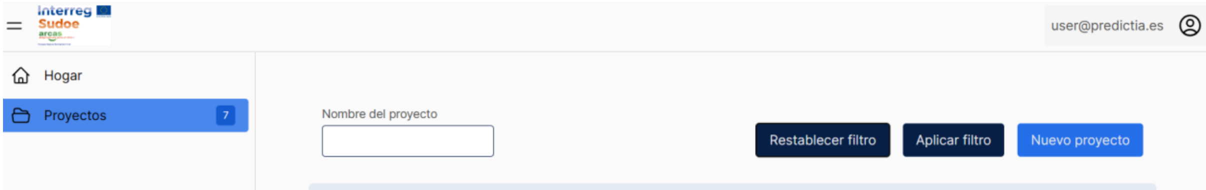
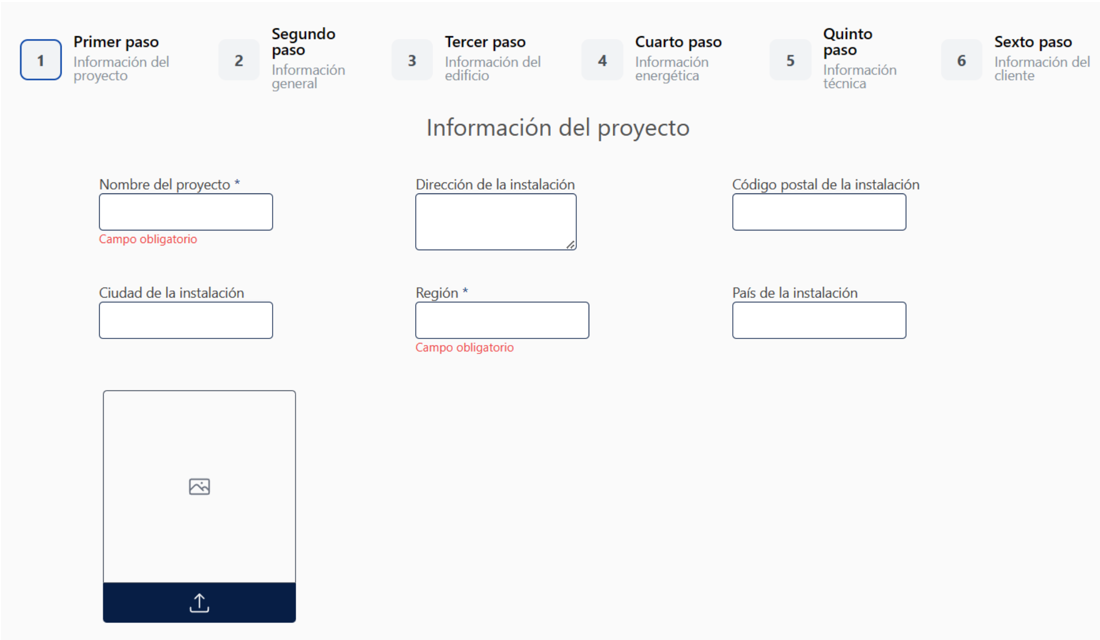
Project general data. -

We define a new project by entering "Projects" - "New Project"



Next : to enter the project data following these steps :

Step 1 : Project Overview. –



- Project Name: Name we will give to the project. Mandatory Field.
- Address of the building.
- Postal code.
- City.
- SUDOE Region
- Country
- Photo of the building.

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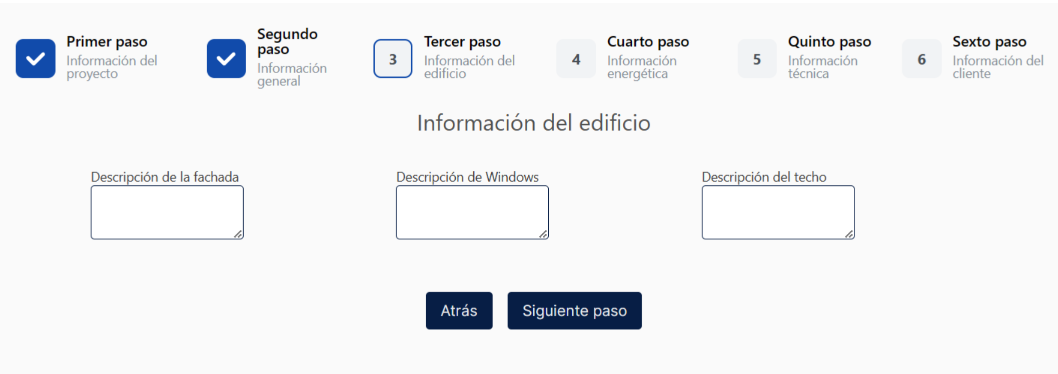
Step 2 : Project Overview. –

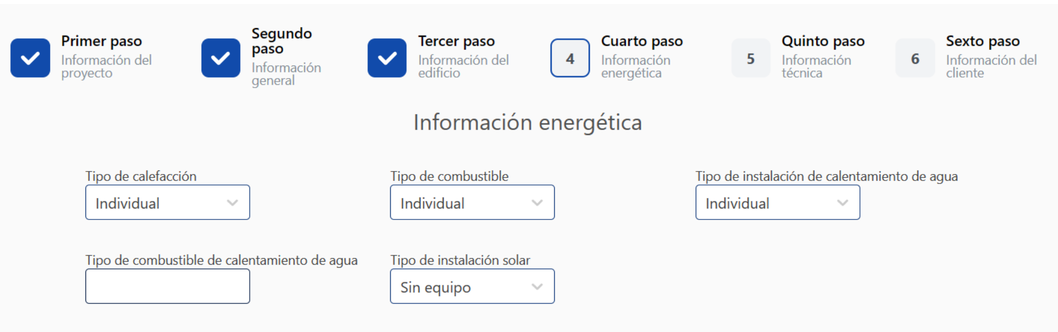
- Latitude
- Length
- Year of construction
- Surface
- Governing regulations

Step 3 : Building information. -



- General description of the facade.
- Description of windows.
- Description of the cover.
-

Step 4 : Energy information. -



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- Type of heating.
- Type of fuel.
- Type of water heating installation.
- Type of water heating fuel.
- Type of solar installation.

Step 5 : Technical information. –

- Technical name. Mandatory field.
- Address of the technician.
- Postal code of the technician.
- City of the technician
- Region of the technician.
- Country of the technician.
-

Step 6: Customer information. –

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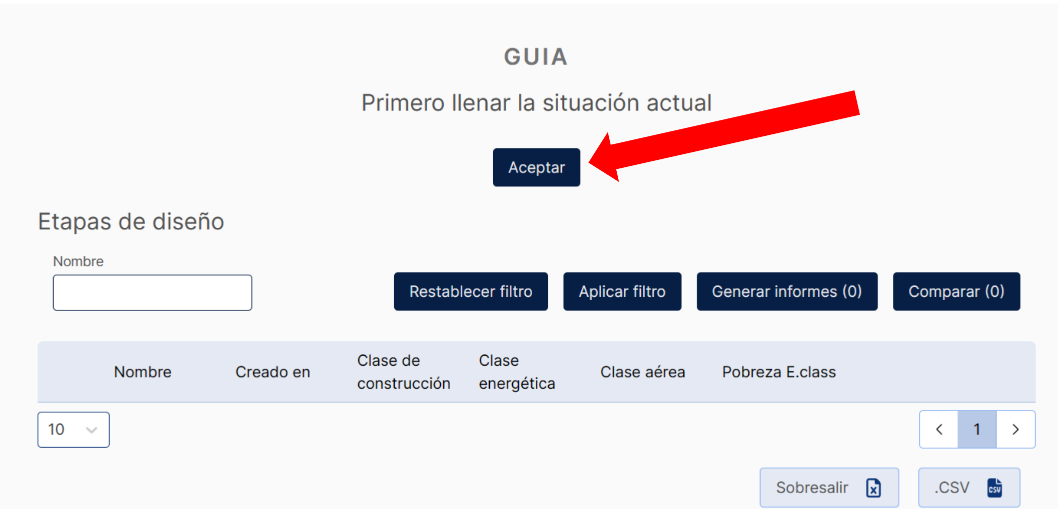
- Customer name. Mandatory field.
- Customer address.
- Postal code of the customer.
- City of the customer.
- Region of the customer.
- Country of customer.

Define the actual situation. –

Once we enter the general data of the project, we go to the main screen, and clicked on "Show the design stages of the building"

A screen opens to cover the current situation of the building:



Clicking on *accept* opens the screens where to enter the indicators according to the 3 axes discussed above.

As we are at user level the indicators can be entered in an estimated way.

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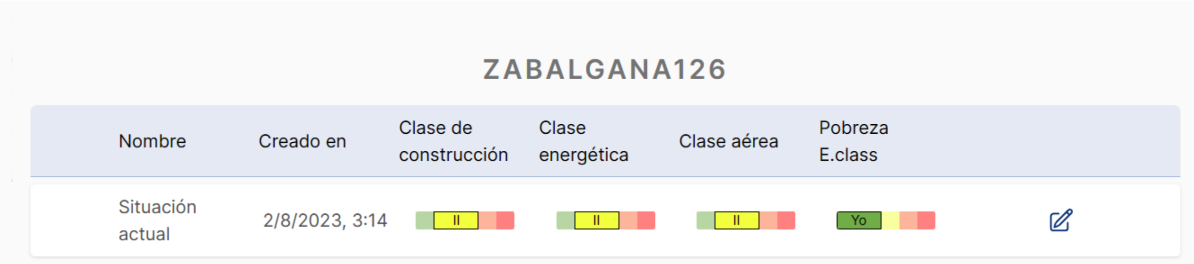
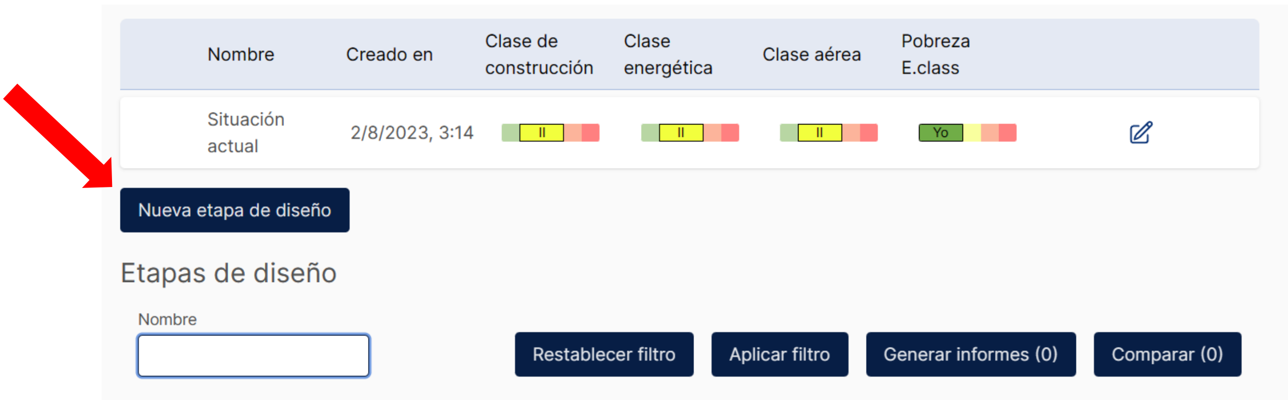
Once the current state has been generated, the traffic light corresponding to each of the axes will appear on the screen:



The indicators are represented by means of a traffic light:

Define the different simulations. –

Clicking on "New design stage" we are simulating different situations:



The tool shows the different simulations studied, with the traffic light of each one:

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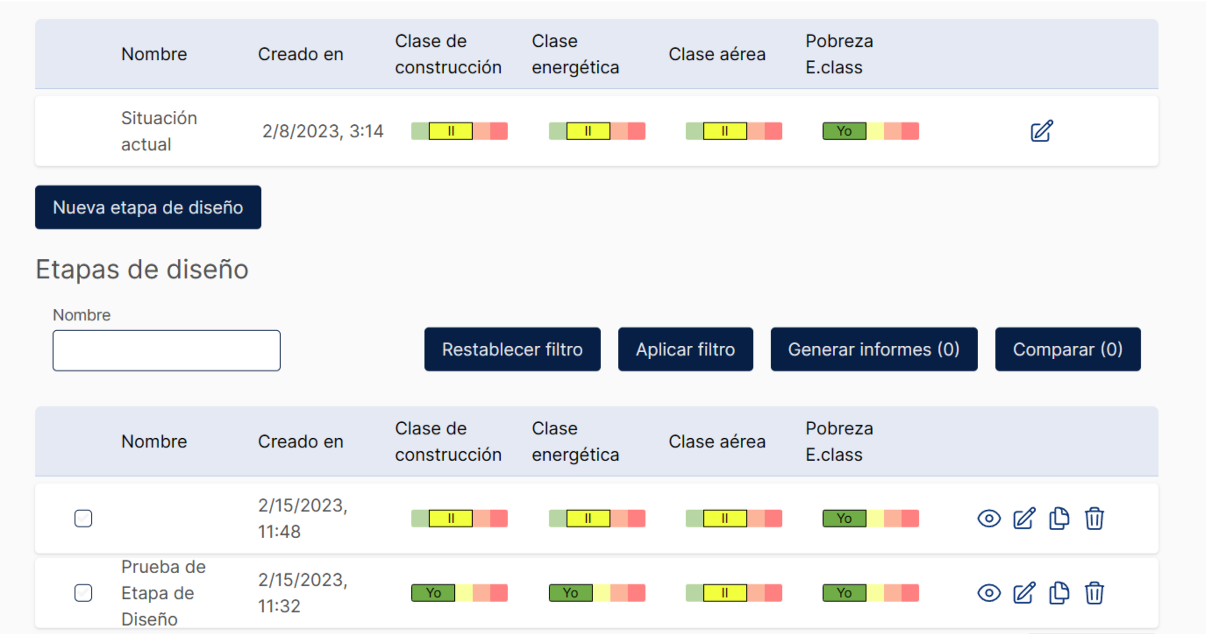
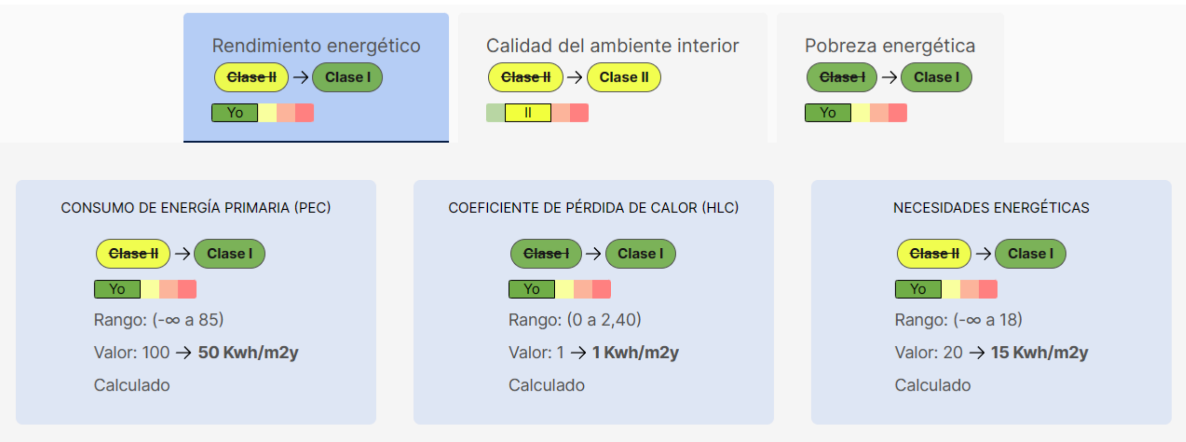


We can make a comparisons between the different simulations and the current state of the building.

All data are visually broken down through the traffic light or circular diagram and numerically, and data can be exported in format. pdf . csv . or Excel.

Comparison between current state and simulation I.

Traffic lights:



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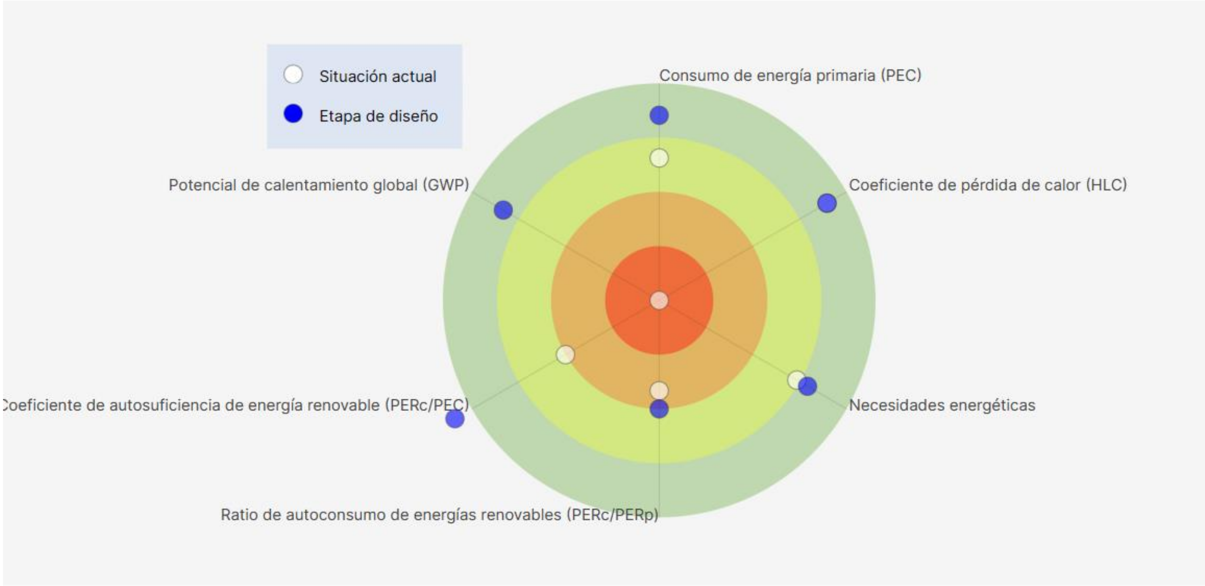
Circular diagram:



Data list :

Eje	Indicador	Valor de la situación actual	Valor de la etapa de diseño	Clase de situación actual	Clase de etapa de diseño	Alcance de la situación actual	Rango de etapa de diseño
Energía	Potencial de calentamiento global (GWP)	0 %	53 %	Clase IV	Clase I	(-∞ a 10)	[30 a ∞)
Energía	Consumo de energía primaria (PEC)	100 Kwh/m2a	50 Kwh/m2a	Clase II	Clase I	[85 a 125]	(-∞ a 85)
Energía	Coeficiente de pérdida de calor (HLC)	1 Kwh/m2	1 Kwh/m2	Clase I	Clase I	(0 a 2,40)	(0 a 2,40)
Energía	energía renovable	40 Kwh/m2a	60 Kwh/m2a	-	-	-	-
Energía	Energía Renovable	60 Kwh/m2a	100 Kwh/m2a	-	-	-	-

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II.7 – Certifier and User Link

In this part we will describe the link between certifier and user using ARCAS

The guide is intended for users who wish to obtain information about the ARCAS methodology when using it. The ARCAS project defines two profiles:

- User profile

The technician checks the initial situation of the building by estimating the indicators that define the 3 indicated axes.

Knowing the initial situation of the building, the tool allows to simulate possible changes by providing a comparison between the initial situation and the different simulations. These benchmarks help decision-making in the measures to be implemented.

- Certifier profile

For the certification of the building with the ARCAS method, the values that are measured or calculated are introduced in the tool, the estimation of these is not valid.

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II.8 - Appendices and bibliographic references 'User's guidebook

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II.8.2 – Appendix 2 : References of II.2.3 – Poverty Efficiency Indicator

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